THE STAR FORMATION NEWSLETTER

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The Star Formation Newsletter

The Star Formation Newsletter is a vehicle for fast distribution of information of interest for astronomers working on star and planet formation and molecular clouds. You can submit material for the following sections: *Abstracts of recently accepted papers* (only for papers sent to refereed journals), *Abstracts of recently accepted major reviews* (not standard conference contributions), *Dissertation Abstracts* (presenting abstracts of new Ph.D dissertations), *Meetings* (announcing meetings broadly of interest to the star and planet formation and early solar system community), *New Jobs* (advertising jobs specifically aimed towards persons within the areas of the Newsletter), and *Short Announcements* (where you can inform or request information from the community). Additionally, the Newsletter brings short overview articles on objects of special interest, physical processes or theoretical results, the early solar system, as well as occasional interviews.

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Cover Picture

The Musca cloud filament is located at an approximate distance of 150 pc and has a projected length of about 6.5 pc. The filament is quiescent, with magnetic field lines perpendicular to the long axis, along which background material may be accreting. Star formation has yet to start in this filament.

Image courtesy Marco Lorenzi

https://www.glitteringlights.com/

Submitting your abstracts

Latex macros for submitting abstracts and dissertation abstracts (by e-mail to reipurth@ifa.hawaii.edu) are appended to each Call for Abstracts. You can also submit via the Newsletter web interface at http://www2.ifa.hawaii.edu/star-formation/index.cfm

Abstracts of recently accepted papers

1 HST spectra reveal accretion in MY Lupi

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The mass accretion rate is a crucial parameter for the study of the evolution of accretion discs around young low-mass stellar and substellar objects (YSOs). We revisit the case of MY Lup, an object where VLT/X-Shooter data suggested a negligible mass accretion rate, and show it to be accreting on a level similar to other Class II YSOs in Lupus based on Hubble Space Telescope (HST) observations. In our HST-Cosmic Origins Spectrograph (HST-COS) and -Space Telescope Imaging Spectrograph (HST-STIS) spectra, we find many emission lines, as well as substantial far-ultraviolet (FUV) continuum excess emission, which can be ascribed to active accretion. The total luminosity of the C IV λ1549 Å doublet is $4.1\times10^{-4}\,L_\odot$. Using scalings between accretion luminosity, $L_{\rm acc}$, and C IV luminosity from the literature, we derive $L_{\rm acc}{\sim}2\times10^{-1}L_\odot$, which is more than an order of magnitude higher than the upper limit estimated from the X-Shooter observations. We discuss possible reasons for the X-Shooter-HST discrepancy, the most plausible being that the low contrast between the continuum excess emission and the photospheric+chromospheric emission at optical wavelengths in MY Lup hampered detection of excess emission. The luminosity of the FUV continuum and C IV lines, strong H_2 fluorescence, and a "1600 A Bump" place MY Lup in the class of accreting objects with gas-rich discs. So far, MY Lup is the only peculiar case in which a significant difference between the HST and X-Shooter $\dot{M}_{\rm acc}$ estimates exists that is not ascribable to variability. The mass accretion rate inferred from the revisited $L_{\rm acc}$ estimate is $\dot{M}_{\rm acc} \sim 1(^{+1.5}_{-0.5})\times10^{-8}$ M$_\odot$ yr^{-1}. This value is consistent with the typical value derived for accreting YSOs of similar mass in Lupus and points to less clearing of the inner disc than indicated by near- and mid-infrared observations. This is confirmed by Atacama Large Millimeter Array (ALMA) data, which show that the gaps and rings seen in the sub-millimetre are relatively shallow.

Accepted by Astronomy and Astrophysics

https://arxiv.org/pdf/1908.10647

2 Gaia DR2 distances to Collinder 419 and NGC 2264 and new astrometric orbits for HD 193 322 Aa,Ab and 15 Mon Aa,Ab

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Context. Gaia DR2 has opened a trove of astrometric and photometric data for Galactic clusters close to the Sun. Lucky imaging has been an operational technique to measure the positions of visual binary systems for a decade and a half, enough to apply its results to the calculation of orbits of some massive multiple systems within ~1 kpc of the Sun.
Aims. We are measuring distances to Galactic stellar groups containing O stars and I start with two of them: Collinder 419 in Cygnus and NGC 2264 in Monoceros. I also aim to derive new astrometric orbits for the Aa,Ab components

for the main ionizing sources for both clusters: HD 193 322 and 15 Mon, respectively.
Methods. I present a method that uses Gaia DR2 photometry, positions, proper motions, and parallaxes to obtain the membership and distance of a stellar group and apply it to Collinder 419 and NGC 2264. Second, I present a new code that calculates astrometric orbits by searching the whole 7-parameter orbit space and apply it to HD 193 322 Aa,Ab and 15 Mon Aa,Ab using as input literature data from the Washington Double Star Catalog (WDS) and the AstraLux measurements recently presented by Maz Apellniz et al. (2019).
Results. I obtain Gaia DR2 distances of 1006^{+37}_{-34} pc for Collinder 419 and 719±16 pc for NGC 2264, with the main contribution to the uncertainties coming from the spatial covariance of the parallaxes. The two NGC 2264 subclusters are at the same distance (within the uncertainties) and they show a significant relative proper motion. The distances are shown to be robust. HD 193 322 Aa,Ab follows an eccentric ($e = 0.58^{+0.03}_{-0.04}$) orbit with a period of 44±1 a and the three stars it contains have a total mass of $76.1^{+9.9}_{-7.4}$ $M_\odot$. The orbit of 15 Mon Aa,Ab is even more eccentric ($e = 0.770^{+0.023}_{-0.030}$), with a period of 108±12 a and a total mass of $45.1^{+3.6}_{-3.3}$ $M_\odot$ for its two stars.

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3 Inner rocky super-Earth formation: distinguishing the formation pathways in viscously heated and passive discs

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The formation of super-Earths is strongly linked to the structure of the protoplanetary disc, which determines growth and migration. In the pebble accretion scenario, planets grow to the pebble isolation mass, at which the planet carves a small gap in the gas disc halting the pebble flux and thus its growth. The pebble isolation mass scales with the disc's aspect ratio, which directly depends on the disc structure. I compare the growth of super-Earths in viscously heated discs and discs purely heated by the central star with super-Earth observations. This allows two formation pathways of super-Earths to be distinguished in the inner systems. Planets growing within 1 Myr in the viscously heated inner disc reach pebble isolation masses that correspond directly to the inferred masses of the Kepler observations for systems that feature planets in resonance or not in resonance. However, to explain the period ratio distribution of Kepler planets — where most Kepler planet pairs are not in mean motion resonance configurations — a fraction of these resonant chains has to be broken. In case the planets are born early in a viscously heated disc, these resonant chains thus have to be broken without planetary mergers. If super-Earths form either late or in purely passive discs, the pebble isolation mass is too small to explain the Kepler observations, implying that planetary mergers are important for the final system architecture. Resonant planetary systems thus have to experience mergers already during the gas disc phase, so the planets can get trapped in resonance after reaching 5–10 Earth masses. In case instabilities are dominating the system architecture, the systems should not be flat with mutually inclined orbits. This implies that future observations of planetary systems with RV and transits could distinguish between these two formation channels of super-Earth.

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http://arxiv.org/pdf/1908.08710

4 The First Detection of $^{13}C^{17}O$ in a Protoplanetary Disk: a Robust Tracer of Disk Gas Mass

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Measurements of the gas mass are necessary to determine the planet formation potential of protoplanetary disks. Observations of rare CO isotopologues are typically used to determine disk gas masses; however, if the line emission is optically thick this will result in an underestimated disk mass. With ALMA we have detected the rarest stable CO isotopologue, $^{13}C^{17}O$, in a protoplanetary disk for the first time. We compare our observations with the existing detections of ^{12}CO, ^{13}CO, $C^{18}O$ and $C^{17}O$ in the HD163296 disk. Radiative transfer modelling using a previously benchmarked model, and assuming interstellar isotopic abundances, significantly underestimates the integrated intensity of the $^{13}C^{17}O$ J=3–2 line. Reconciliation between the observations and the model requires a global increase in CO gas mass by a factor of 3.5. This is a factor of 2–6 larger than previous gas mass estimates using $C^{18}O$. We find that $C^{18}O$ emission is optically thick within the CO snow line, while the $^{13}C^{17}O$ emission is optically thin and is thus a robust tracer of the bulk disk CO gas mass.

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The fulcrum wavelength of young stellar objects – the case of LRLL 31

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A small subset of young stellar objects (YSOs) exhibit "see-saw" temporal variations in their mid-infrared SED; as the flux short-ward of a fulcrum wavelength (λ_f) increases the flux long-wards of this wavelength decreases (and vice-versa) over timescales of weeks to years. While previous studies have shown that an opaque, axisymmetric occulter of variable height can cause this behaviour in the SED of these objects, the conditions under which a single λ_f occurs have not previously been determined, nor the factors determining its value. Using radiative transfer modelling, we conduct a parametric study of the exemplar of this class, LRLL 31 to explore this phenomenon, and confirm that the cause of this flux variation is likely due to the change in height of the optically thick inner rim of the accretion disc at the dust sublimation radius, or some other phenomenon which results in a similar appearance. We also determine that a fulcrum wavelength only occurs for high inclinations, where the line of sight intersects the accretion disc. Accepting that the disc of LRLL 31 is highly inclined, the inner rim radius, radial and vertical density profiles are independently varied to gauge what effect this had on λ_f and its position relative to the silicate feature near 10 μm. While λ_f is a function of each of these parameters, it is found to be most strongly dependent on the vertical density exponent β. All other factors being held constant, only for flatter discs ($\beta < 1.2$) did we find a λ_f beyond the silicate feature.

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Radial Drift and Concurrent Ablation of Boulder-Sized Objects

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Context. The composition of a protoplanetary disk at a given location does not only depend on temperature and pressure but also on the time dependent transport of matter, such as radial drift of solid bodies, which could release water and other volatile species before disintegration or accretion onto a larger body with potentially considerable implications for the composition of planets.
Aims. We perform a parameter study focused on the water depletion of different sized bodies able to cross the water snowline by gas induced radial drift.
Methods. Either the analytical Hertz-Knudsen-Langmuir sublimation formula assuming equilibrium temperature

within the body or a more involved, numerical model for the internal thermal evolution is coupled with an α-disk model. Different properties of the disk and the embedded body are explored.
Results. Bodies with radii up to 100 meter drift faster towards the central star than the water snowline, hence, cross it. The region that can be reached before complete disintegration — and is therefore polluted with H_2O ice — extends to 10 percent closer to the star than the snowline location. The extent of this polluted region could be multiple times larger in the presence of a dust mantle, which is, however, unlikely to form due to frequent collisions with smaller-than centimeter sized objects.
Conclusions. Given a significant abundance of meter sized boulders in protoplanetary disks, the transport of water by radial drift of these bodies towards regions closer to the star than the snowline is not negligible and this flux of volatiles can be estimated for a given distribution of solid body sizes and compositions. A simple expression for surface sublimation is applicable for a homogeneous body consisting of only dust and water ice without a dust mantle.

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http://arxiv.org/pdf/1908.02513

7 The Structure of Dark Molecular Gas in the Galaxy – II. Physical State of "CO-Dark" Gas in the Perseus Arm

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We report the results from a new, highly sensitive ($\Delta T_{mb} \sim$ 3mK) survey for thermal OH emission at 1665 and 1667 MHz over a dense, 9 × 9-pixel grid covering a 1°× 1° patch of sky in the direction of $l = 105°$, $b = +2\overset{\circ}{.}50$ towards the Perseus spiral arm of our Galaxy. We compare our Green Bank Telescope (GBT) 1667 MHz OH results with archival CO J=1–0 observations from the Five College Radio Astronomy Observatory (FCRAO) Outer Galaxy Survey within the velocity range of the Perseus Arm at these galactic coordinates. Out of the 81 statistically-independent pointings in our survey area, 86% show detectable OH emission at 1667 MHz, and 19% of them show detectable CO emission. We explore the possible physical conditions of the observed features using a set of diffuse molecular cloud models. In the context of these models, both OH and CO disappear at current sensitivity limits below an A_V of 0.2, but the CO emission does not appear until the volume density exceeds 100–200 cm^{-3}. These results demonstrate that a combination of low column density A_V and low volume density $n_{\rm H}$ can explain the lack of CO emission along sight lines exhibiting OH emission. The 18-cm OH main lines, with their low critical density of $n^* \sim 1$ cm^{-3}, are collisionally excited over a large fraction of the quiescent galactic environment and, for observations of sufficient sensitivity, provide an optically-thin radio tracer for diffuse H_2.

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8 Stars and brown dwarfs in the sigma Orionis cluster. IV. IDS/INT and OSIRIS/GTC spectroscopy and Gaia DR2 astrometry

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Context. Only a few open clusters are as important for the study of stellar and substellar objects, and their formation and evolution, as the young σ Orionis cluster. However, a complete spectroscopic characterisation of its whole stellar population is still missing.
Aims. We filled most of that gap with a large spectroscopic and astrometric survey of targets towards σ Orionis. Eventually, it will be one of the open clusters with the lowest proportion of interlopers and the largest proportion of confirmed cluster members with known uncontrovertible youth features.
Methods. We acquired 317 low-resolution optical spectra with the Intermediate Dispersion Spectrograph (IDS) at the 2.5 m Isaac Newton Telescope (INT) and the Optical System for Imaging and low Resolution Integrated Spectroscopy (OSIRIS) at the 10.4 m Gran Telescopio Canarias (GTC). We measured equivalent widths of Li I, Hα, and other key lines from these spectra, and determined spectral types. We complemented this information with *Gaia* DR2 astrometric data and other features of youth (mid-infrared excess, X-ray emission) compiled with Virtual Observatory tools and from the literature.
Results. Of the 168 observed targets, we determined for the first time spectral types of 39 stars and equivalent widths of Li I and Hα of 34 and 12 stars, respectively. We identified 11 close ($\rho \lesssim 3''$) binaries resolved by *Gaia*, of which three are new, 14 strong accretors, of which four are new and another four have Hα emission shifted by over 120 km s^{-1}, two juvenile star candidates in the sparse population of the Ori OB1b association, and one spectroscopic binary candidate. Remarkably, we found 51 non-cluster-members, 35 of which were previously considered as sigma Orionis members and taken into account in high-impact works on, for example, disc frequency and initial mass function.

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http://arxiv.org/pdf/1908.10340

9 Dust accretion in binary systems: implications for planets and transition discs

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The presence of planets in binary systems poses interesting problems for planet formation theories, both in cases where planets must have formed in very compact discs around the individual stars and where they are located near the edge of the stable circumbinary region, where in situ formation is challenging. Dust dynamics is expected to play an important role in such systems, since dust trapping at the inner edge of circumbinary discs could aid in situ formation, but would simultaneously starve the circumstellar discs of the solid material needed to form planets. Here we investigate the dynamics of dust in binary systems using Smooth Particle Hydrodynamics. We find that all our simulations tend towards dust trapping in the circumbinary disc, but the timescale on which trapping begins depends on binary mass ratio (q) and eccentricity as well as the angular momentum of the infalling material. For $q \gtrsim 0.1$, we find that dust can initially accrete onto the circumstellar discs, but as the circumbinary cavity grows in radius, dust eventually becomes trapped in the circumbinary disc. For $q = 0.01$, we find that increasing the binary eccentricity increases the time required for dust trapping to begin. However, even this longer timescale is likely to be shorter than the planet formation timescale in the inner disc and is insufficient to explain the observed pre-transitional discs. This indicates that increase in companion eccentricity alone is not enough to allow significant transfer of solids from the outer to the inner disc.

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10 How do velocity structure functions trace gas dynamics in simulated molecular clouds?

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Context. Supersonic disordered flows accompany the formation and evolution of MCs. It has been argued that turbulence can support against gravitational collapse and form hierarchical sub-structures.
Aims. We study the time evolution of simulated MCs to investigate: What physical process dominates the driving of turbulent flows? How can these flows be characterised? Do the simulated flows agree with observations?
Methods. We analyse three MCs that have formed self-consistently within kpc-scale numerical simulations of the ISM. The simulated ISM evolves under the influence of physical processes including self-gravity, stratification, magnetic fields, supernova-driven turbulence, and radiative heating and cooling. We characterise the flows using VSFs with/out density weighting or a density cutoff, and computed in one or three dimensions.
Results. In regions with sufficient resolution, the density-weighted VSFs initially appear to follow the expectations for uniform turbulence consistent with Larson's size-velocity relationship. SN blast wave impacts produce short-lived coherent motions at large scales, increasing the scaling exponents for a crossing time. Gravitational contraction drives small-scale motions, producing scaling coefficients that drop or even turn negative as small scales become dominant.
Conclusions. We conclude that two different effects coincidentally reproduce Larson's size velocity relationship. Initially, uniform turbulence dominates, so the energy cascade produces VSFs consistent with Larson's relationship. Later, contraction dominates, the density-weighted VSFs become much shallower or even inverted, but the relationship of the global average velocity dispersion of the MCs to their radius follows Larson's relationship, reflecting virial equilibrium or free-fall collapse. The injection of energy by shocks is visible in the VSFs, but decays within a crossing time.

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11 A VLT/FLAMES survey for massive binaries in Westerlund 1: VII. Cluster census

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The formation, properties, and evolution of massive stars remain subject to considerable uncertainty; impacting on fields as diverse as galactic feedback and the nature of the progenitors of both electromagnetic and gravitational wave transients. The clusters many such stars reside within provide a unique laboratory for addressing these issues, and in this work we provide a comprehensive stellar census of Westerlund 1 to underpin such efforts. 69 new members were identified via I-band spectroscopy, yielding a total cluster population of 166 stars with initial masses of $\sim 25 M_\odot$ to $\sim 50 M_\odot$, with more massive stars already lost to supernova. The stellar population follows a smooth and continuous morphological sequence from late-O giant through to OB supergiant. Subsequently, the progression bifurcates, with one branch yielding mid- to late-B hypergiants and cool super-/hypergiants, and the other massive blue stragglers, prior to a diverse population of H-depleted Wolf-Rayets. A substantial population of O-type stars with anomalously broad Paschen series lines are seen, a property which we attribute to binarity. Binary interaction is clearly required to yield the uniquely rich cohort of hypergiants, which includes both mass-stripped primaries and rejuvenated secondaries/stellar mergers. As a consequence future observations of Wd1 and similar stellar aggregates hold out the prospect of characterising both single- and binary- evolutionary channels for massive stars and determining their relative contributions. This in turn will permit the physical properties of such objects at the point of core-collapse to be predicted; of direct relevance for understanding the formation of relativistic remnants such as the magnetars associated with Wd1 and other young massive clusters.

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12 Pebbles versus Planetesimals: The case of Trappist-1

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We present a study on the formation of planetary systems around low mass stars similar to Trappist-1, through the accretion of either planetesimals or pebbles. The aim is to determine if the currently observed systems around low mass stars favour one scenario over the other. We ran numerous N-body simulations, coupled to a thermally evolving viscous disc model, including prescriptions for planet migration and photoevaporation. We examine the differences between the pebble and planetesimal accretion scenarios, but also look at the influences of disc mass, planetesimal size, and the percentage of solids locked up within pebbles. When comparing the resulting planetary systems to Trappist-1, we find that a wide range of initial conditions for both accretion scenarios can form planetary systems similar to Trappist-1, in terms of planet mass, periods, and resonant configurations. Typically these planets formed exterior to the water iceline and migrated in resonant convoys to close to the central star. When comparing the planetary systems formed from pebbles to those formed from planetesimals, we find a large number of similarities, including average planet masses, eccentricities, inclinations and period ratios. One major difference was that of the water content of the planets. When including the effects of ablation and full recycling of the planets envelope with the disc, planets formed from pebbles were extremely dry, whilst those formed from planetesimals were extremely wet. If the water content is not fully recycled and instead falls to the planets core, or if ablation of the water is neglected, then the planets formed from pebbles are extremely wet, similar to those formed from planetesimals. Should the water content of the Trappist-1 planets be determined accurately, this could point to a preferred formation pathway for planetary systems, or to specific physics that may be at play.

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13 Effects of Radiation in Accretion Regions of Classical T Tauri Stars: Pre-heating of accretion column in non-LTE regime

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Models and observations indicate that the impact of matter accreting onto the surface of young stars produces regions at the base of accretion columns, in which optically thin and thick plasma components coexist. Thus an accurate description of these impacts requires to account for the effects of absorption and emission of radiation. We study the effects of radiation emerging from shock-heated plasma in impact regions on the structure of the pre-shock downfalling material. We investigate if a significant absorption of radiation occurs and if it leads to a pre-shock heating of the accreting gas. We developed a radiation hydrodynamics model describing an accretion column impacting onto the surface of a Classical T Tauri Star. The model takes into account the stellar gravity, the thermal conduction, and the effects of both radiative losses and absorption of radiation by matter in the non local thermodynamic equilibrium regime. After the impact, a hot slab of post-shock plasma develops at the base of the accretion column. Part of radiation emerging from the slab is absorbed by the pre-shock accreting material. As a result, the pre-shock accretion column gradually heats up to temperatures of 10^5 K, forming a radiative precursor of the shock. The precursor has a thermal structure with the hottest part at $T \approx 10^5$ K, with size comparable to that of the hot slab, above the post-shock region. At larger distances the temperature gradually decreases to $T \approx 10^4$ K.

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14 Interstellar Plunging Waves: ALMA resolves the physical structure of non-stationary MHD shocks

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Magneto-hydrodynamic (MHD) shocks are violent events that inject large amounts of energy in the interstellar medium (ISM) dramatically modifying its physical properties and chemical composition. Indirect evidence for the presence of such shocks has been reported from the especial chemistry detected toward a variety of astrophysical shocked environments. However, the internal physical structure of these shocks remains unresolved since their expected spatial scales are too small to be measured with current instrumentation. Here we report the first detection of a fully spatially resolved, MHD shock toward the Infrared Dark Cloud (IRDC) G034.77-00.55. The shock, probed by Silicon Monoxide (SiO) and observed with the Atacama Large Millimetre/sub-millimetre Array (ALMA), is associated with the collision between the dense molecular gas of the cloud and a molecular gas flow pushed toward the IRDC by the nearby supernova remnant (SNR) W44. The interaction is occurring on sub-parsec spatial scales thanks to the enhanced magnetic field of the SNR, making the dissipation region of the MHD shock large enough to be resolved with ALMA. Our observations suggest that molecular flow- flow collisions can be triggered by stellar feedback, inducing shocked molecular gas densities compatible with those required for massive star formation.

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15 Resolved ALMA continuum image of the circumbinary ring and circumstellar disks in the L1551 IRS 5 system

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L1551 IRS 5 is a FUor-like object located in the Taurus star forming region. We present ALMA 1.3 mm continuum observations using a wide range of baselines. The observations recovered the two circumstellar disks composing the system and, for the first time, resolved the circumbinary ring. We determined the geometry and estimated lower mass limits for the circumstellar disks using simple models. We calculated lower limits for the total mass of both circumstellar disks. After subtracting the two circumstellar disk models from the image, the residuals show a clearly resolved circumbinary ring. Using a radiative transfer model, we show that geometrical effects can explain some of the brightness asymmetries found in the ring. The remaining features are interpreted as enhancements in the dust density.

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16 Onset of planet formation in the warm inner disk – Colliding dust aggregates at high temperatures

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Collisional growth of dust occurs in all regions of protoplanetary disks with certain materials dominating between various condensation lines. The sticking properties of the prevalent dust species depend on the specific temperatures. The inner disk is the realm of silicates spanning a wide range of temperatures from room temperature up to sublimation beyond 1500 K. For the first time, we carried out laboratory collision experiments with hot levitated basalt dust aggregates of 1 mm in size. The aggregates are compact with a filling factor of 0.37±0.06. The constituent grains have a wide size distribution that peaks at about 0.6 μm. Temperatures in the experiments are varied between approximately 600 K and 1100 K. Collisions are slow with velocities between 0.002 m s^{-1} and 0.15 m s^{-1}, i.e., relevant for protoplanetary disks. Aside from variations of the coefficients of restitution due to varying collision velocities, the experiments show low sticking probability below 900 K and an increasing sticking probability starting at 900 K. This implies that dust can grow to larger size in hot regions, which might change planet formation. One scenario is an enhanced probability for local planetesimal formation. Another scenario is a reduction of planetesimal formation as larger grains are more readily removed as a consequence of radial drift. However, the increased growth at high temperatures likely changes planetesimal formation one way or the other.

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17 Cluster-forming site AFGL 5157: colliding filamentary clouds and star formation

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We observationally investigate star formation (SF) process occurring in AFGL 5157 (area ∼13.5 pc × 13.5 pc) using a multi-wavelength approach. Embedded filaments are seen in the *Herschel* column density map, and one of them is identified as an elongated filamentary feature (FF) (length ∼8.3 pc; mass ∼1170 $M_\odot$). Five *Herschel* clumps (M_{clump} ∼45–300 $M_\odot$) are traced in the central part of FF, where an extended temperature structure (T_d ∼13.5–26.5 K) is observed. In the direction of the central part of FF, the warmer region at T_d ∼20–26.5 K spatially coincides with a mid-infrared (MIR) shell surrounding a previously known evolved infrared cluster. Diffuse Hα emission is traced inside the infrared shell, suggesting the presence of massive stars in the evolved cluster. Based on the surface density analysis of young stellar objects (YSOs), embedded clusters of YSOs are traced toward the central part of FF, and are distributed around the infrared shell. Previously detected H_2O masers, H_2 knots, massive protostar candidates, and H II region are also seen toward the embedded clusters. Using the ^{12}CO and ^{13}CO line data, the central part of FF is observed at the overlapping zones of two filamentary molecular clouds (length ∼12.5 pc) around −20 and −17 km s^{-1}, which are also connected in velocity. Our observational results suggest that the formation of massive stars appears to be triggered by a collision of two filamentary molecular clouds, which might have also influenced the birth of YSOs in AFGL 5157.

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18 Star formation activity and the spatial distribution and mass segregation of dense cores in the early phases of star formation

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We examine the spatial distribution and mass segregation of dense molecular cloud cores in a number of nearby star forming regions (the region L1495 in Taurus, Aquila, Corona Australis, and W43) that span about four orders of magnitude in star formation activity. We used an approach based on the calculation of the minimum spanning tree, and for each region, we calculated the structure parameter $\mathcal{Q}$ and the mass segregation ratio $\Lambda_{\rm MSR}$ measured for various numbers of the most massive cores. Our results indicate that the distribution of dense cores in young star forming regions is very substructured and that it is very likely that this substructure will be imprinted onto the nascent clusters that will emerge out of these clouds. With the exception of Taurus in which there is nearly no mass segregation, we observe mild-to-significant levels of mass segregation for the ensemble of the 6, 10, and 14 most massive cores in Aquila, Corona Australis, and W43, respectively. Our results suggest that the clouds' star formation activity are linked to their structure, as traced by their population of dense cores. We also find that the fraction of massive cores that are the most mass segregated in each region correlates with the surface density of star formation in the clouds. The Taurus region with low star forming activity is associated with a highly hierarchical spatial distribution of the cores (low $\mathcal{Q}$ value) and the cores show no sign of being mass segregated. On the other extreme, the mini-starburst region W43-MM1 has a higher $\mathcal{Q}$ that is suggestive of a more centrally condensed structure. Additionally, it possesses a higher fraction of massive cores that are segregated by mass. While some limited evolutionary effects might be present, we largely attribute the correlation between the star formation activity of the clouds and their structure to a dependence on the physical conditions that have been imprinted on them by the large scale environment at the time they started to assemble

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19 Measuring the ionisation fraction in a jet from a massive protostar

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It is important to determine if massive stars form via disc accretion, like their low-mass counterparts. Theory and observation indicate that protostellar jets are a natural consequence of accretion discs and are likely to be crucial for removing angular momentum during the collapse. However, massive protostars are typically rarer, more distant and more dust enshrouded, making observational studies of their jets more challenging. A fundamental question is whether the degree of ionisation in jets is similar across the mass spectrum. Here we determine an ionisation fraction of $\sim 5-12\%$ in the jet from the massive protostar G35.20-0.74N, based on spatially coincident infrared and radio emission. This is similar to the values found in jets from lower-mass young stars, implying a unified mechanism of shock ionisation applies in jets across most of the protostellar mass spectrum, up to at least ~ 10 solar masses.

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20 Measuring the magnetic field of young stars using iSHELL observations: BP Tau and V347 Aur

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While it has been suggested that there is a connection between the magnetic properties and the internal structure of

young stars, there have not been enough magnetic measurements to firmly establish such a correlation at the earliest ages. Here, we contribute to this endeavor by presenting stellar parameters and magnetic field strength measurements of BP Tau and V347 Aur, both stars observed with the near-infrared spectrograph iSHELL. We first test the accuracy of our method by fitting synthetic stellar spectra to a sample of nine main and post-main-sequence stars. We report uncertainties of $\sigma_{\rm Teff} = 91$ K in temperature and $\sigma_{\log(g)} = 0.14$ in gravity. We then apply the modeling technique to BP Tau and measure a surface magnetic field strength of $\langle B \rangle = 2.5^{+0.15}_{-0.16}$ kG, confirming literature results. For this star, however, we obtain a much lower temperature value than previous optical studies ($\Delta T \sim 400$ K) and interpret this significant temperature difference as due to the relatively higher impact of starspots at near-infrared wavelengths than at optical wavelengths. We further apply this technique to the class I protostellar source V347 Aur and measure for the first time its magnetic field strength $\langle B \rangle = 1.36^{+0.06}_{-0.05}$ kG and its surface gravity $\log(g) = 3.25^{+0.14}_{-0.14}$. Lastly, we combine our measurements with pre-main-sequence stellar evolutionary models and illustrate the effects produced by starspots on the retrieved masses and ages of young stars.

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21 Origin of the PN molecule in star-forming regions: the enlarged sample

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Phosphorus nitride (PN) is the P-bearing species with the highest number of detections in star-forming regions. Multi-line studies of the molecule have shown that the excitation temperature of PN is usually lower than the gas kinetic temperature, suggesting that PN is likely in conditions of sub-thermal excitation. We present an analysis of PN which takes the possible sub-thermal excitation conditions into account in a sample of 24 massive star-forming regions. We observed PN (2–1), (3–2), (4–3), and (6–5) with the IRAM-30m and APEX telescopes and detected PN lines in 15 of them. Together with 9 similar sources detected in PN in previous works, we have analysed the largest sample of star-forming regions to date, made of 33 sources with 24 detections in total (among which 13 are new detections). Hence, we have increased the number of star-forming regions detected in PN by more than a factor 2. Our analysis indicates that the PN lines are indeed sub-thermally excited, but well described by a single excitation temperature. We have compared line profiles and fractional abundances of PN and SiO, a typical shock tracer, and found that almost all objects detected in PN have high-velocity SiO wings. Moreover, the SiO and PN abundances with respect to H_2 are correlated over several orders of magnitude, and uncorrelated with gas temperature. This clearly shows that the production of PN is strongly linked to the presence of shocked gas, and rules out alternative scenarios based on thermal evaporation from iced grain mantles.

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22 H_2 ortho-para spin conversion on inhomogeneous grain surfaces

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We investigate the evolution of the ortho-to-para ratio of overall (gas + ice) H_2 via the nuclear spin conversion on grain surfaces coated with water ice under physical conditions that are relevant to star- and planet-forming regions.

We utilize the rate equation model that considers adsorption of gaseous H_2 on grain surfaces which have a variety of binding sites with a different potential energy depth, thermal hopping, desorption, and the nuclear spin conversion of adsorbed H_2. It is found that the spin conversion efficiency depends on the H_2 gas density and the surface temperature. As a general trend, enhanced H_2 gas density reduces the efficiency, while the temperature dependence is not monotonic; there is a critical surface temperature at which the efficiency is the maximum. At low temperatures, the exchange of gaseous and icy H_2 is inefficient (i.e., adsorbed H_2 does not desorb and hinders another gaseous H_2 to be adsorbed), while at warm temperatures, the residence time of H_2 on surfaces is too short for the spin conversion. Additionally, the spin conversion becomes more efficient with lowering the activation barriers for thermal hopping. We discuss whether the spin conversion on surfaces can dominate over that in the gas-phase in star- and planet-forming regions. Finally, we establish a simple but accurate way to implement the H_2 spin conversion on grain surfaces in existing astrochemical models.

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23 Structure and kinematics of the Taurus star-forming region from Gaia-DR2 and VLBI astrometry

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Aims: We take advantage of the second data release of the Gaia space mission and the state-of-the-art astrometry delivered from very long baseline interferometry observations to revisit the structure and kinematics of the nearby Taurus star-forming region.

Methods: We apply a hierarchical clustering algorithm for partitioning the stars in our sample into groups (i.e., clusters) that are associated with the various molecular clouds of the complex, and derive the distance and spatial velocity of individual stars and their corresponding molecular clouds.

Results: We show that the molecular clouds are located at different distances and confirm the existence of important depth effects in this region reported in previous studies. For example, we find that the L 1495 molecular cloud is located at $d = 129.9^{+0.4}_{-0.3}$ pc, while the filamentary structure connected to it (in the plane of the sky) is at $d = 160.0^{+1.2}_{-1.2}$ pc. We report B 215 and L 1558 as the closest ($d = 128.5^{+1.6}_{-1.6}$ pc) and most remote ($d = 198.1^{+2.5}_{-2.5}$ pc) substructures of the complex, respectively. The median inter-cloud distance is 25 pc and the relative motion of the subgroups is on the order of a few km/s. We find no clear evidence for expansion (or contraction) of the Taurus complex, but signs of the potential effects of a global rotation. Finally, we compare the radial velocity of the stars with the velocity of the underlying ^{13}CO molecular gas and report a mean difference of 0.04 ± 0.12 km/s (with r.m.s. of 0.63 km/s) confirming that the stars and the gas are tightly coupled.

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24 Linking planetesimal and dust content in protoplanetary disks via a local toy model

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If planetesimal formation is an efficient process, as suggested by several models involving gravitational collapse of pebble clouds, then, before long, a significant part of the primordial dust mass should be absorbed in many km sized objects. A good understanding of the total amount of solids in the disk around a young star is crucial for planet formation theory. But as the mass of particles above the mm size cannot be assessed observationally, one must ask how much mass is hidden in bigger objects. We perform 0-d local simulations to study how the planetesimal to dust and pebble ratio is evolving in time and to develop an understanding of the potentially existing mass in planetesimals for a certain amount of dust and pebbles at a given disk age. We perform a parameter study based on a model considering dust growth, planetesimal formation and collisional fragmentation of planetesimals, while neglecting radial transport processes. While at early times, dust is the dominant solid particle species, there is a phase during which planetesimals make up a significant portion of the total mass starting at approximately 10^4–10^6 yr. The time of this phase and the maximal total planetesimal mass strongly depend on the distance to the star R, the initial disk mass, and the efficiency of planetesimal formation ϵ. After approximately 10^6 yr, our model predicts planetesimal collisions to dominate, which resupplies small particles. In our model, planetesimals form fast and everywhere in the disk. For a given ϵ, we were able to relate the dust content and mass of a given disk to its planetesimal content, providing us with some helpful basic intuition about mass distribution of solids and its dependence on underlying physical processes.

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25 Chondrule Formation by the Jovian Sweeping Secular Resonance

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Chondrules are silicate spheroids found in meteorites, serving as important fossil records of the early solar system. In order to form chondrules, chondrule precursors must be heated to temperatures much higher than the typical conditions in the current asteroid belt. One proposed mechanism for chondrule heating is the passage through bow shocks of highly eccentric planetesimals in the protoplanetary disk in the early solar system. However, it is difficult for planetesimals to gain and maintain such high eccentricities. In this paper, we present a new scenario in which planetesimals in the asteroid belt region are excited to high eccentricities by the Jovian sweeping secular resonance in a depleting disk, leading to efficient formation of chondrules. We study the orbital evolution of planetesimals in the disk using semi-analytic models and numerical simulations. We investigate the dependence of eccentricity excitation on the planetesimal's size as well as the physical environment, and calculate the probability for chondrule formation. We find that 50–2000 km planetesimals can obtain eccentricities larger than 0.6 and cause effective chondrule heating. Most chondrules form in high velocity shocks, in low density gas, and in the inner disk. The fraction of chondrule precursors which become chondrules is about 4–9% between 1.5–3 au. Our model implies that the disk depletion timescale is $\tau_{\rm dep} \approx 1$ Myr, comparable to the age spread of chondrules; and that Jupiter formed before chondrules, no more than 0.7 Myr after the formation of the CAIs.

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26 Close-in giant-planet formation via in-situ gas accretion and their natal disk properties

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The origin of close-in Jovian planets is still elusive. We examine the in-situ gas accretion scenario as a formation mechanism of these planets. We reconstruct natal disk properties from the occurrence rate distribution of close-in giant planets, under the assumption that the occurrence rate may reflect the gas accretion efficiency onto cores of these planets. We find that the resulting gas surface density profile becomes an increasing function of the distance from the central star with some structure at $r \simeq 0.1$ au. This profile is quite different from the standard minimum-mass solar nebula model, while our profile leads to better reproduction of the population of observed close-in super-Earths based on previous studies. We compute the resulting magnetic field profiles and find that our profiles can be fitted by stellar dipole fields ($\propto r^{-3}$) in the vicinity of the central star and large-scale fields ($\propto r^{-2}$) at the inner disk regions, either if the isothermal assumption breaks down or if non-ideal MHD effects become important. For both cases, the transition between these two profiles occurs at $r \simeq 0.1$ au, which corresponds to the period valley of giant exoplanets. Our work provides an opportunity to test the in-situ gas accretion scenario against disk quantities, which may constrain the gas distribution of the minimum-mass *extra* solar nebula.

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27 How first hydrostatic cores, tidal forces and gravo-turbulent fluctuations set the characteristic mass of stars

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The stellar initial mass function (IMF) is playing a critical role in the history of our universe. We propose a theory that is based solely on local processes, namely the dust opacity limit, the tidal forces and the properties of the collapsing gas envelope. The idea is that the final mass of the central object is determined by the location of the nearest fragments, which accrete the gas located further away, preventing it to fall onto the central object. To estimate the relevant statistics in the neighbourhood of an accreting protostar, we perform high resolution numerical simulations. We also use these simulations to further test the idea that fragmentation in the vicinity of an existing protostar is determinant in setting the peak of the stellar mass spectrum. We develop an analytical model, which is based on a statistical counting of the turbulent density fluctuations, generated during the collapse, that are at least equal to the mass of the first hydrostatic core, and sufficiently important to supersede tidal and pressure forces to be self-gravitating. The analytical mass function presents a peak located at roughly 10 times the mass of the first hydrostatic core in good agreement with the numerical simulations. Since the physical processes involved are all local, i.e. occurs at scales of a few 100 AU or below, and do not depend on the gas distribution at large scale and global properties such as the mean Jeans mass, the mass spectrum is expected to be relatively universal.

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28 First sub-arcsecond submillimeter-wave [C I] image of 49 Ceti with ALMA

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We present the first sub-arcsecond images of 49 Ceti in the [C I] $^3P_1$–$^3P_0$ emission and the 614 μm dust continuum emission observed with ALMA, as well as that in the CO(J=3–2) emission prepared by using the ALMA archival data. The spatial distribution of the 614 μm dust continuum emission is found to have a broad-ring structure with a radius of about 100 au around the central star. A substantial amount of gas is also associated with 49 Ceti. The [C I] emission map shows two peaks inside the dust ring, and its overall extent is comparable to that of the dust continuum emission and the CO emission. We find that the [C I]/CO(J=3–2) intensity ratio significantly varies along the major axis. The ratio takes the minimum value of 1.8 around the dust peak position, and increases inwards and outwards. The enhanced ratio around the central star ($\sim$3) likely originates from the stellar UV radiation, while that in the outer disk ($\sim$10) from the interstellar UV radiation. Such complex distributions of the [C I] and CO(J=3–2) emission will be a key to understand the origin of the gas in 49 Ceti, and will also provide a stringent constraint on physical and chemical models of gaseous debris disks.

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L1495 Revisited: A PPMAP View of a Star-Forming Filament

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We have analysed the *Herschel* and SCUBA-2 dust continuum observations of the main filament in the Taurus L1495 star forming region, using the Bayesian fitting procedure PPMAP. (i) If we construct an average profile along the whole length of the filament, it has FWHM $\simeq 0.087 \pm 0.003$ pc; , but the closeness to previous estimates is coincidental. (ii) If we analyse small local sections of the filament, the column-density profile approximates well to the form predicted for hydrostatic equilibrium of an isothermal cylinder. (iii) The ability of PPMAP to distinguish dust emitting at different temperatures, and thereby to discriminate between the warm outer layers of the filament and the cold inner layers near the spine, leads to a significant reduction in the surface-density, Σ, and hence in the line-density, μ. If we adopt the canonical value for the critical line-density at a gas-kinetic temperature of 10 K, $\mu_{\rm CRIT} \simeq 16\,{\rm M_\odot\,pc^{-1}}$, the filament is on average trans-critical, with $\bar{\mu} \sim \mu_{\rm CRIT}$; local sections where $\mu > \mu_{\rm CRIT}$ tend to lie close to pre-stellar cores. (iv) The ability of PPMAP to distinguish different types of dust, i.e. dust characterised by different values of the emissivity index, β, reveals that the dust in the filament has a lower emissivity index, $\beta \leq 1.5$, than the dust outside the filament, $\beta \geq 1.7$, implying that the physical conditions in the filament have effected a change in the properties of the dust.

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Nobeyama 45 m Mapping Observations toward Orion A. II. Classification of cloud structures and variation of the ^{13}CO/C^{18}O abundance ratio due to far-UV Radiation

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We present results of the classification of cloud structures toward the Orion A Giant Molecular Cloud based on wide-field ^{12}CO ($J = 1$–0), ^{13}CO ($J =$ 1-0), and C^{18}O ($J =$ 1-0) observations using the Nobeyama 45 m radio telescope. We identified 78 clouds toward Orion A by applying Spectral Clustering for Interstellar Molecular Emission Segmentation (SCIMES) to the data cube of the column density of ^{13}CO. Well-known subregions such as OMC-1, OMC-2/3, OMC-4, OMC-5, NGC 1977, L1641-N, and the dark lane south filament (DLSF) are naturally identified as distinct structures in Orion A. These clouds can also be classified into three groups: the integral-shaped filament, the southern regions of Orion A, and the other filamentary structures in the outer parts of Orion A and the DLSF. These groups show differences in scaling relations between the physical properties of the clouds. We derived the abundance ratio between ^{13}CO and C^{18}O, $X_{^{13}\mathrm{CO}}/X_{\mathrm{C}^{18}\mathrm{O}}$, which ranges from 5.6 to 17.4 on median over the individual clouds. The significant variation of $X_{^{13}\mathrm{CO}}/X_{\mathrm{C}^{18}\mathrm{O}}$, is also seen within a cloud in both of the spatial and velocity directions and the ratio tends to be high at the edge of the cloud. The values of $X_{^{13}\mathrm{CO}}/X_{\mathrm{C}^{18}\mathrm{O}}$, decrease from 17 to 10 with the median of the column densities of the clouds at the column density of $N_{\mathrm{C}^{18}\mathrm{O}} \gtrsim 1 \times 10^{15}$ cm^{-2} or visual extinction of $A_V \gtrsim 3$ mag under the strong far-ultraviolet (FUV) environment of $G_0 > 10^3$, whereas it is almost independent of the column density in the weak FUV radiation field. These results are explained if the selective photodissociation of C18O is enhanced under a strong FUV environment and it is suppressed in the dense part of the clouds.

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31 New evidence for weak magnetic fields in Herbig Ae/Be stars

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In recent years Herbig Ae/Be stars receive considerable attention as their disks are believed to be the sites of on-going planet formation. Confirming the presence of magnetic fields in these stars is critical for understanding the transport of angular momentum during the protostellar phase. Furthermore, magnetic fields set the conditions for strongly anisotropic accretion. In this study we present the results of our recent observing campaigns of a sample of Herbig Ae/Be stars aimed at measurements of their magnetic fields applying the Singular Value Decomposition method to high resolution spectropolarimetric observations. The strongest longitudinal magnetic field of 209 G is detected in the Herbig Be star HD 58647, whereas the weakest field of 17 G is measured in the Herbig Ae star HD 190073. A change of polarity is detected for HD 58647 and in the Herbig Be star HD 98922. The obtained results provide further evidence that Herbig Ae/Be stars possess much weaker magnetic fields than their lower mass counterpart T Tauri stars with magnetic fields of kG order.

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32 Dynamical Gaseous Rings in Global Simulations of Protoplanetary Disk Formation

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Global numerical simulations of protoplanetary disk formation and evolution were conducted in thin-disk limit, where the model included magnetically layered disk structure, a self-consistent treatment for the infall from cloud core as well as the smallest possible inner computational boundary. We compared the evolution of a layered disk with a fully magnetically active disk. We also studied how the evolution depends on the parameters of the layered disk model — the MRI triggering temperature and active layer thickness — as well as the mass of the prestellar cloud core. With the canonical values of parameters a dead zone formed within the inner ≈ 15 au region of the magnetically layered disk. The dead zone was not a uniform structure and long-lived, axisymmetric, gaseous rings ubiquitously formed within this region due to the action of viscous torques. The rings showed a remarkable contrast in the disk environment as compared to a fully magnetically active disk and were characterized by high surface density and low effective viscosity. Multiple gaseous rings could form simultaneously in the dead zone region which were highly dynamical and showed complex, time-dependent behavior such as inward migration, vortices, gravitational instability and large-scale spiral waves. An increase in MRI triggering temperature had only marginal effects, while changes in active layer thickness as well as the initial cloud core mass had significant effects on the structure and evolution of the inner disk. Dust with large fragmentation barrier could be trapped in the rings, which may play a key role in planet formation.

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33 Abundant refractory sulfur in protoplanetary disks

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Sulfur is one of the most abundant elements in the Universe, with important roles in astro-, geo-, and biochemistry. Its main reservoirs in planet-forming disks have previously eluded detection: gaseous molecules only account for <1% of total elemental sulfur, with the rest likely in either ices or refractory minerals. Mechanisms such as giant planets can filter out dust from gas accreting onto disk-hosting stars. For stars above 1.4 solar masses, this leaves a chemical signature on the stellar photosphere that can be used to determine the fraction of each element that is locked in dust. Here, we present an application of this method to sulfur, zinc, and sodium. We analyse the accretion-contaminated photospheres of a sample of young stars and find (89±8)% of elemental sulfur is in refractory form in their disks. The main carrier is much more refractory than water ice, consistent with sulfide minerals such as FeS.

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34 Constraining the detectability of water ice in debris disks

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Water ice is important for the evolution and preservation of life. Identifying the distribution of water ice in debris disks is therefore of great interest in the field of astrobiology. Furthermore, icy dust grains are expected to play important roles throughout the entire planet formation process. However, currently available observations only allow deriving weak conclusions about the existence of water ice in debris disks. We investigate whether it is feasible to detect water ice in typical debris disk systems. We take the following ice destruction mechanisms into account: sublimation of ice, dust production through planetesimal collisions, and photosputtering by UV-bright central stars. We consider icy dust mixture particles with various shapes consisting of amorphous ice, crystalline ice, astrosilicate, and vacuum inclusions (i.e., porous ice grains). We calculated optical properties of inhomogeneous icy dust mixtures using effective medium theories, that is, Maxwell-Garnett rules. Subsequently, we generated synthetic debris disk observables, such as spectral energy distributions and spatially resolved thermal reemission and scattered light intensity and polarization maps with our code DMS. We find that the prominent $\sim 3\ \mu$m and 44 μm water ice features can be potentially detected in future observations of debris disks with the James Webb Space Telescope (JWST) and the Space Infrared telescope for Cosmology and Astrophysics (SPICA). We show that the sublimation of ice, collisions between planetesimals, and photosputtering caused by UV sources clearly affect the observational appearance of debris disk systems. In addition, highly porous ice (or ice-rich aggregates) tends to produce highly polarized radiation at around 3 μm. Finally, the location of the ice survival line is determined by various dust properties such as a fractional ratio of ice versus dust, physical states of ice (amorphous or crystalline), and the porosity of icy grains.

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35 Molecular envelope around the HII region RCW 120

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The HII region RCW 120 is a well-known object, which is often considered as a target to verify theoretical models of gas and dust dynamics in the interstellar medium. However, the exact geometry of RCW 120 is still a matter of debate. In this work, we analyse observational data on molecular emission in RCW 120 and show that ^{13}CO(2–1) and C^{18}O(2–1) lines are fitted by a 2D model representing a ring-like face-on structure. The changing of the C^{18}O(3–2) line profile from double-peaked to single-peaked from the dense molecular Condensation 1 might be a signature of stalled expansion in this direction. In order to explain a self-absorption dip of the ^{13}CO(2–1) and ^{13}CO(3–2) lines, we suggest that RCW 120 is surrounded by a diffuse molecular cloud, and find confirmation of this cloud on a map of interstellar extinction. Optically thick ^{13}CO(2–1) emission and the infrared 8 μm PAH band form a neutral envelope of the HII region resembling a ring, while the envelope breaks into separate clumps on images made with optically thin C^{18}O(2–1) line and far-infrared dust emission.

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36 A Comparison of the X-ray Properties of FU Ori-type Stars to Generic Young Stellar Objects

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Like other young stellar objects (YSOs), FU Ori-type stars have been detected as strong X-ray emitters. However, little is known about how the outbursts of these stars affect their X-ray properties. We assemble available X-ray data from *XMM Newton* and *Chandra* observations of 16 FU Ori stars, including a new *XMM Newton* observation of Gaia 17bpi during its optical rise phase. Of these stars, six were detected at least once, while 10 were non-detections, for which we calculate upper limits on intrinsic X-ray luminosity (L_X) as a function of plasma temperature (kT) and column density (N_H). The detected FU Ori stars tend to be more X-ray luminous than typical for non-outbursting YSOs, based on comparison to a sample of low-mass stars in the Orion Nebula Cluster. FU Ori stars with high L_X

have been observed both at the onset of their outbursts and decades later. We use the Kaplan-Meier estimator to investigate whether the higher X-ray luminosities for FU Ori stars is characteristic or a result of selection effects, and we find the difference to be statistically significant ($p < 0.01$) even when non-detections are taken into account. The additional X-ray luminosity of FU Ori stars relative to non-outbursting YSOs cannot be explained by accretion shocks, given the high observed plasma temperatures. This suggests that, for many FU Ori stars, either 1) the outburst leads to a restructuring of the magnetosphere in a way that enhances X-ray emission, or 2) FU Ori outbursts are more likely to occur among YSOs with the highest quiescent X-ray luminosity.

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Disk Formation in Magnetized Dense Cores with Turbulence and Ambipolar Diffusion

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Disks are essential to the formation of both stars and planets, but how they form in magnetized molecular cloud cores remains debated. This work focuses on how the disk formation is affected by turbulence and ambipolar diffusion (AD), both separately and in combination, with an emphasis on the protostellar mass accretion phase of star formation. We find that a relatively strong, sonic turbulence on the core scale strongly warps but does not completely disrupt the well-known magnetically-induced flattened pseudodisk that dominates the inner protostellar accretion flow in the laminar case, in agreement with previous work. The turbulence enables the formation of a relatively large disk at early times with or without ambipolar diffusion, but such a disk remains strongly magnetized and does not persist to the end of our simulation unless a relatively strong ambipolar diffusion is also present. The AD-enabled disks in laminar simulations tend to fragment gravitationally. The disk fragmentation is suppressed by initial turbulence. The ambipolar diffusion facilitates the disk formation and survival by reducing the field strength in the circumstellar region through magnetic flux redistribution and by making the field lines there less pinched azimuthally, especially at late times. We conclude that turbulence and ambipolar diffusion complement each other in promoting disk formation. The disks formed in our simulations inherit a rather strong magnetic field from its parental core, with a typical plasma-β of order a few tens or smaller, which is 2-3 orders of magnitude lower than the values commonly adopted in MHD simulations of protoplanetary disks. To resolve this potential tension, longer-term simulations of disk formation and evolution with increasingly more realistic physics are needed.

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Evaluation of nearby young moving groups based on unsupervised machine learning

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Nearby young stellar moving groups have been identified by many research groups with different methods and criteria giving rise to cautions on the reality of some groups. We aim to utilise moving groups in an unbiased way to create a list of unambiguously recognisable moving groups and their members. For the analysis, two unsupervised machine learning algorithms (K-means and Agglomerative Clustering) are applied to previously known bona fide members of nine moving groups from our previous study. As a result of this study, we recovered six previously known groups (AB Doradus, Argus, β-Pic, Carina, TWA, and Volans-Carina). Three the other known groups are recognised as well; however, they are combined into two new separate groups (ThOr+Columba and TucHor+Columba).

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39 ## Characterizing Magnetic Field Morphologies in Three Serpens Protostellar Cores with ALMA

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With the aim of characterizing the dynamical processes involved in the formation of young protostars, we present high angular resolution ALMA dust polarization observations of the Class 0 protostellar cores Serpens SMM1, Emb 8(N), and Emb 8. With spatial resolutions ranging from 150 to 40 au at 870 μm, we find unexpectedly high values of the polarization fraction along the outflow cavity walls in Serpens Emb8(N). We use 3 mm and 1 mm molecular tracers to investigate outflow and dense gas properties and their correlation with the polarization. These observations allow us to investigate the physical processes involved in the Radiative Alignment Torques (RATs) acting on dust grains along the outflow cavity walls, which experience irradiation from accretion processes and outflow shocks. The inner core of SMM1-a presents a polarization pattern with a poloidal magnetic field at the bases of the two lobes of the bipolar outflow. To the south of SMM1-a we see two polarized filaments, one of which seems to trace the redshifted outflow cavity wall. The other may be an accretion streamer of material infalling onto the central protostar. We propose that the polarized emission we see at millimeter wavelengths along the irradiated cavity walls can be reconciled with the expectations of RAT theory if the aligned grains present at ¡ 500 au scales in Class 0 envelopes have grown larger than the 0.1 μm size of ISM dust grains. Our observations allow us to constrain the star-forming sources magnetic field morphologies within the central cores, along the outflow cavity walls, and in possible accretion streamers.

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40 ## Diagnosing 0.1–10 au scale morphology of the FU Ori disk using ALMA and VLTI/GRAVITY

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We report new Atacama Large Millimeter/submillimeter Array Band 3 (86–100 GHz; ∼80 mas angular resolution) and Band 4 (146–160 GHz; ∼50 mas angular resolution) observations of the dust continuum emission towards the archetypal and ongoing accretion burst young stellar object FU Ori, which simultaneously covered its companion, FU Ori S. In addition, we present near-infrared (2–2.45 μm) observations of FU Ori taken with the General Relativity Analysis via VLT InTerferometrY (GRAVITY; ∼1 mas angular resolution) instrument on the Very Large Telescope Interferometer (VLTI). We find that the emission in both FU Ori and FU Ori S at (sub)millimeter and near infrared bands is dominated by structures inward of ∼10 au radii. We detected closure phases close to zero from FU Ori with VLTI/GRAVITY, which indicate the source is approximately centrally symmetric and therefore is likely viewed nearly face-on. Our simple model to fit the GRAVITY data shows that the inner 0.4 au radii of the FU Ori disk has a triangular spectral shape at 2–2.45 μm, which is consistent with the H_2O and CO absorption features in a $\dot{M} \sim 10^{-4}$ $M_\odot$ yr^{-1}, viscously heated accretion disk. At larger (∼0.4–10 au) radii, our analysis shows that viscous heating may also explain the observed (sub)millimeter and centimeter spectral energy distribution when we assume a constant, $\sim 10^{-4}$ $M_\odot$ yr^{-1} mass inflow rate in this region. This explains how the inner 0.4 au disk is replenished with mass at a modest rate, such that it neither depletes nor accumulates significant masses over its short dynamic timescale. Finally, we tentatively detect evidence of vertical dust settling in the inner 10 au of the FU Ori disk, but confirmation requires more complete spectral sampling in the centimeter bands.

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41 Constraining the Formation of the Four Terrestrial Planets in the Solar System

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To reproduce the orbits and masses of the terrestrial planets (analogs) of the solar system, most studies scrutinize simulations for success as a batch. However, there is insufficient discussion in the literature on the likelihood of forming planet analogs simultaneously in the same system (analog system). To address this issue, we performed 540 N-body simulations of protoplanetary disks representative of typical models in the literature. We identified a total of 194 analog systems containing at least three analogs, but only 17 systems simultaneously contained analogs of the four terrestrial planets. From an analysis of our analog systems, we found that, compared to the real planets, truncated disks based on typical outcomes of the Grand Tack model produced analogs of Mercury and Mars that were too dynamically cold and located too close to the Venus and Earth analogs. Additionally, all the Mercury analogs were too massive, while most of the Mars analogs were more massive than Mars. Furthermore, the timing of the Moon-forming impact was too early in these systems, and the amount of additional mass accreted after the event was too great. Therefore, such truncated disks cannot explain the formation of the terrestrial planets. Our results suggest that forming the four terrestrial planets requires disks with the following properties: 1) Mass concentrated in narrow core regions between ∼0.7–0.9 and ∼1.0–1.2 au; 2) an inner region component starting at ∼0.3–0.4 au; 3) a less massive component beginning at ∼1.0–1.2 au; 4) embryos rather than planetesimals carrying most of the disk mass; and 5) Jupiter and Saturn placed on eccentric orbits.

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42 Runaway Young Stars in the Orion Nebula

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The star forming region of the Orion Nebula (ONC) is ideal to study the stellar dynamics of young stars in a clustered environment. Using Gaia DR2 we search for the pre-main sequence stars with unusually high proper motions that may be representative of a dynamical ejection from unstable young triple systems or other close three-body encounters. We identify twenty-six candidate stars that are likely to have had such an encounter in the last 1 Myr. Nine of these stars could be traced back to the densest central-most region of the ONC, the Trapezium, while five others have likely interactions with other OB-type stars in the cluster. Seven stars originate from other nearby populations within the Orion Complex that coincidentally scattered towards the ONC. A definitive point of origin cannot be identified for the remaining sources. These observations shed light on the frequency of the ejection events in young clusters.

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43 The physical and chemical structure of Sagittarius B2 – V. Non-thermal emission in the envelope of Sgr B2

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The giant molecular cloud Sagittarius B2 (hereafter SgrB2) is the most massive region with ongoing high-mass star formation in the Galaxy. In the southern region of the 40-pc large envelope of SgrB2, we encounter the SgrB2(DS) region which hosts more than 60 high-mass protostellar cores distributed in an arc shape around an extended HII region. We use the Very Large Array in its CnB and D configurations, and in the frequency bands C (4–8 GHz) and X (8–12 GHz) to observe the whole SgrB2 complex. Continuum and radio recombination line maps are obtained. We detect radio continuum emission in SgrB2(DS) in a bubble-shaped structure. From 4 to 12 GHz, we derive a spectral index between -1.2 and -0.4, indicating the presence of non-thermal emission. We decompose the contribution from thermal and non-thermal emission, and find that the thermal component is clumpy and more concentrated, while the non-thermal component is more extended and diffuse. The radio recombination lines in the region are found to be not in local thermodynamic equilibrium (LTE) but stimulated by the non-thermal emission. The thermal free-free emission is likely tracing an HII region ionized by an O7 star, while the non-thermal emission can be generated by relativistic electrons created through first-order Fermi acceleration. We have developed a simple model of the SgrB2(DS) region and found that first-order Fermi acceleration can reproduce the observed flux density and spectral index.

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44 The chemical structure of the very young starless core L1521E

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L1521E is a dense starless core in Taurus that was found to have relatively low molecular depletion by earlier studies, thus suggesting a recent formation.
We aim to characterize the chemical structure of L1521E and compare it to the more evolved L1544 pre-stellar core.
We have obtained ∼2.5×2.5 arcminute maps toward L1521E using the IRAM-30m telescope in transitions of various species, including $C^{17}O$, CH_3OH, c-C_3H_2, CN, SO, H_2CS, and CH_3CCH. We derived abundances for the observed species and compared them to those obtained toward L1544. We estimated CO depletion factors using the $C^{17}O$ IRAM-30m map, an $N(H_2)$ map derived from *Herschel*/SPIRE data and a 1.2 mm dust continuum emission map obtained with the IRAM-30m telescope.
Similarly to L1544, c-C_3H_2 and CH_3OH peak at different positions. Most species peak toward the c-C_3H_2 peak including C_2S, C_3S, HCS^+, HC_3N, H_2CS, CH_3CCH, and $C^{34}S$. $C^{17}O$ and SO peak close to both the c-C_3H_2 and the CH_3OH peaks. CN and N_2H^+ peak close to the *Herschel* dust peak. We found evidence of CO depletion toward L1521E. The lower limit of the CO depletion factor derived toward the *Herschel* dust peak is 4.3±1.6, which is about a factor of three lower than toward L1544. We derived abundances for several species toward the dust peaks of L1521E and L1544. The abundances of most sulfur-bearing molecules such as C_2S, HCS^+, $C^{34}S$, $C^{33}S$, and HCS^+ are higher toward L1521E than toward L1544 by factors of ∼2-20, compared to the abundance of A-CH_3OH. The abundance of methanol is very similar toward the two cores.
The fact that the abundances of sulfur-bearing species toward L1521E are higher than toward L1544 suggests that significant sulfur depletion takes place during the dynamical evolution of dense cores, from the starless to pre-stellar stage. The CO depletion factor measured toward L1521E suggests that CO is more depleted than previously found. Similar CH_3OH abundances between L1521E and L1544 hint that methanol is forming at specific physical conditions in the Taurus Molecular Cloud Complex, characterized by densities of a few $\times 10^4$ cm^{-3} and $N(H_2) \gtrsim 10^{22}$ cm^{-2}, when CO starts to catastrophically freeze-out, while water can still be significantly photodissociated, so that the surfaces of dust grains become rich in solid CO and CH_3OH, as already found toward L1544. Methanol can thus provide selective crucial information about the transition region between dense cores and the surrounding parent cloud.

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45 First clear detection of the CCS Zeeman splitting toward the pre-stellar core, Taurus Molecular Cloud-1

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We report a first clear detection of the Zeeman splitting of a CCS emission line at 45 GHz toward a nearby prestellar dense filament, Taurus Molecular Cloud-1. We observed HC_3N non-Zeeman line simultaneously as the CCS line, and did not detect any significant splitting of HC_3N line. Thus, we conclude that our detection of the CCS Zeeman splitting is robust. The derived line-of-sight magnetic field strength is about 117 ± 21 μG, which corresponds to the normalized mass-to-magnetic flux ratio of 2.2 if we adopt the inclination angle of 45°. Thus, we conclude that the TMC-1 filament is magnetically supercritical. Recent radiative transfer calculations of CCS and HC_3N lines along the line of sight suggest that the filament is collapsing with a speed of ~ 0.6 km s^{-1}, which is comparable to three times the isothermal sound speed. This infall velocity appears to be consistent with the evolution of a gravitationally-infalling core.

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Variability of H_α emission in young stellar objects in the cluster IC 348

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H_α emission is one of the most prominent features of young stellar objects in the optical range, and importantly, the equivalent width of H_α emission (EW(H_α)) is used to characterize an evolutionary stage of young stars.
The aim of this work is to identify and study the stellar objects with variable EW(H_α) in the young stellar cluster IC 348. We performed photometric and slit-less observations at several epochs in order to reveal the variable objects. Significant variability of EW(H_α) was found in 90 out of 127 examined stars. From all epochs of observations, 32 objects were classified as CTT (classical T Tauri) and 69 as WTT (weak-line T Tauri) objects. The fraction of the variables in these samples is about 60%. We also identified 20 stellar objects, which showed not only a significant variability of the equivalent width, but which also change their apparent evolutionary stage (CTT $\Longleftrightarrow$ WTT). For 6 stars, H_α line was observed both in emission and in absorption.
The analysis of data obtained over a wide wavelength range (from X-ray to mid-infrared) has shown that H_α activity and the measure of its variability are in good agreement with the activity of stellar objects measured with its other parameters, such as X-ray radiation and the mass accretion rate. The EW(H_α) differs not only between objects at different evolutionary stages, but also between variable and non-variable objects. The variables in the CTT and WTT samples are more active than non-variables although they have almost the same evolutionary age. Another distinct difference between these variables and non-variables is their average masses. The variables from both CTT and WTT samples are noticeably more massive than non-variables. Our data confirm the assumption made for other star formation regions, that the decay of accretion activity occurs more slowly for more massive CTT objects. Apparently, a similar trend is also present in WTT objects, which are at a later stage of evolution. The variability of the stellar objects, which change their evolutionary classes (CTT $\Longleftrightarrow$ WTT), at least in a fraction of them, is due to the fact that they are close binaries, which affects and modulates their H_α emission activity.

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47

Impact of Cosmic-Ray Feedback on Accretion and Chemistry in Circumstellar Disks

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We use the gas-grain chemistry code UCLCHEM to explore the impact of cosmic-ray feedback on the chemistry of circumstellar disks. We model the attenuation and energy losses of the cosmic-rays as they propagate outwards from the star and also consider ionization due to stellar radiation and radionuclides. For accretion rates typical of young stars, $\dot{M}_* \sim 10^{-9}$–10^{-6} $M_\odot$ yr^{-1}, we show that cosmic rays accelerated by the stellar accretion shock produce a cosmic-ray ionization rate at the disk surface $\zeta \geq 10^{-15}$ s^{-1}, at least an order of magnitude higher than the ionization rate associated with the Galactic cosmic-ray background. The incident cosmic-ray flux enhances the disk ionization at intermediate to high surface densities ($\Sigma > 10$ g cm^{-2}) particularly within 10 au of the star. We find the dominant ions are C^+, S^+ and Mg^+ in the disk surface layers, while the H_3^+ ion dominates at surface densities above 1.0 g cm^{-2}. We predict the radii and column densities at which the magneto-rotational instability (MRI) is active in T Tauri disks and show that ionization by cosmic-ray feedback extends the MRI-active region towards the disk mid-plane. However, the MRI is only active at the mid-plane of a minimum mass solar nebula disk if cosmic-rays propagate diffusively ($\zeta \propto r^{-1}$) away from the star. The relationship between accretion, which accelerates cosmic rays, the dense accretion columns, which attenuate cosmic rays, and the MRI, which facilitates accretion, create a cosmic-ray feedback loop that mediates accretion and may produce luminosity variability.

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48 Non-thermal emission from cosmic rays accelerated in HII regions

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Radio observations at metre-centimetre wavelengths shed light on the nature of the emission of HII regions. Usually this category of objects is dominated by thermal radiation produced by ionised hydrogen, namely protons and electrons. However, a number of observational studies have revealed the existence of HII regions with a mixture of thermal and non-thermal radiation. The latter represents a clue as to the presence of relativistic electrons. However, neither the interstellar cosmic-ray electron flux nor the flux of secondary electrons, produced by primary cosmic rays through ionisation processes, is high enough to explain the observed flux densities. We investigate the possibility of accelerating local thermal electrons up to relativistic energies in HII region shocks. We assumed that relativistic electrons can be accelerated through the first-order Fermi acceleration mechanism and we estimated the emerging electron fluxes, the corresponding flux densities, and the spectral indexes. We find flux densities of the same order of magnitude of those observed. In particular, we applied our model to the 'deep south' (DS) region of Sagittarius B2 and we succeeded in reproducing the observed flux densities with an accuracy of less than 20% as well as the spectral indexes. The model also gives constraints on magnetic field strength ($0.3-4$ mG), density ($1-9\times10^4$ cm^{-3}), and flow velocity in the shock reference frame ($33-50$ km s^{-1}) expected in DS. We suggest a mechanism able to accelerate thermal electrons inside HII regions through the first-order Fermi acceleration. The existence of a local source of relativistic electrons can explain the origin of both the observed non-thermal emission and the corresponding spectral indexes.

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49 Hα emission-line stars in molecular clouds

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A deep objective-prism survey for Hα emission stars towards the Canis Major star forming clouds has been performed. A total of 398 Hα emitters were detected, 353 of which are new detections. There is a strong concentration of these Hα emitters towards the molecular clouds surrounding the CMa OB1 association, and it is likely that these stars are young stellar objects recently born in the clouds. An additional population of Hα emitters is scattered all across the region, and probably includes unrelated foreground dMe stars and background Be stars. About 90% of the Hα emitters are detected by WISE, 75 % with usable photometry. When plotted in a WISE colour-colour diagram it appears that the majority are Class II YSOs. Coordinates and finding charts are provided for all the new stars, and coordinates for all detections. We searched the Gaia-DR2 catalogue and from 334 Hα emission stars with useful parallaxes, we selected a subset of 98 stars which have parallax errors less than 20% and nominal distances in the interval 1050 to 1350 pc that surrounds a strong peak at 1185 pc in the distance distribution. Similarly, Gaia distances were obtained for 51 OB-stars located towards Canis Major and selected with the same parallax errors as the Hα stars. We find a median distance for the OB stars of 1182 pc, in excellent correspondence with the distance from the Hα stars. Two known runaway stars are confirmed as members of the association. Finally, two new Herbig-Haro objects are identified.

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50 Dusty clumps in circumbinary discs

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Recent observations have revealed that protoplanetary discs often exhibit cavities and azimuthal asymmetries such as dust traps and clumps. The presence of a stellar binary system in the inner disc regions has been proposed to explain the formation of these structures. Here, we study the dust and gas dynamics in circumbinary discs around eccentric and inclined binaries. This is done through two-fluid simulations of circumbinary discs, considering different values of the binary eccentricity and inclination. We find that two kinds of dust structures can form in the disc: a single horseshoe-shaped clump, on top of a similar gaseous over-density; or numerous clumps, distributed along the inner disc rim. The latter features form through the complex interplay between the dust particles and the gaseous spirals caused by the binary. All these clumps survive between one and several tens of orbital periods at the feature location. We show that their evolution strongly depends on the gas-dust coupling and the binary parameters. Interestingly, these asymmetric features could in principle be used to infer or constrain the orbital parameters of a stellar companion — potentially unseen — inside the inner disc cavity. Finally, we apply our findings to the disc around AB Aurigae.

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51 Infrared and sub-mm observations of outbursting young stars with Herschel and Spitzer

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Episodic accretion plays an important role in the evolution of young stars. Although it has been under investigation for a long time, the origin of such episodic accretion events is not yet understood. We investigate the dust and gas emission of a sample of young outbursting sources in the infrared to get a better understanding of their properties and circumstellar material, and we use the results in a further work to model the objects. We used Herschel data, from our PI program of 12 objects and complemented with archival observations to obtain the spectral energy distributions (SEDs) and spectra of our targets. We report here the main characteristics of our sample, focussing on the SED properties and on the gas emission lines detected in the PACS and SPIRE spectra. The SEDs of our sample show the diversity of the outbursting sources, with several targets showing strong emission in the far-infrared from the embedded objects. Most of our targets reside in a complex environment, which we discuss in detail. We detected several atomic and molecular lines, in particular rotational CO emission from several transitions from J=38-37 to J=4-3. We constructed rotational diagrams for the CO lines, and derived in three domains of assumed local thermodynamic equilibrium (LTE) temperatures and column densities, ranging mainly between 0-100 K and 400-500 K. We confirm correlation in our sample between intense CO J=16-15 emission and the column density of the warm domain of CO, N(warm). We notice a strong increase in luminosity of HH 381 IRS and a weaker increase for PP 13 S, which shows the beginning of an outburst.

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52 Flares of accretion activity of the 20 Myr old UXOR RZ Psc

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We discuss a revision of accretion activity and kinematics of the enigmatic isolated UX Ori type star RZ Psc. Previously, RZ Psc was known to possess only spectroscopic signatures of outflow in the low-excitation lines of alkali metals. The archival high-resolution spectra reveal a short-lived episode of magnetospheric accretion in the system observed via inverse P Cyg profiles at the Hα and CaII 8542Å lines. The simultaneous presence of accretion and outflow signatures at CaII 8542Å is suggestive of an accretion-driven origin of the RZ Psc wind. We argue that RZ Psc experiences matter ejection via the magnetic propeller mechanism but variable accretion episodes allow it to sometimes move in the magnetospheric accretion regime. The presence of the weak accretion in the system is also supported by the radiation of the hot accretion spot on the stellar surface observed spectroscopically at the deep photometric minimum of the star. The Galactic motion of RZ Psc calculated with new GAIA DR2 astrometric data suggests possible membership in Cas-Tau OB association with an age of $t = 20^{+3}_{-5}$Myr.

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53 Not so different after all: Properties and Spatial Structure of Column Density Peaks in the Pipe and Orion A Clouds

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We present a comparative study of the physical properties and the spatial distribution of column density peaks in two Giant Molecular Clouds (GMC), the Pipe Nebula and Orion A, which exemplify opposite cases of star cluster formation stages. The density peaks were extracted from dust extinction maps constructed from Herschel/SPIRE farinfrared images. We compare the distribution functions for dust temperature, mass, equivalent radius and mean volume density of peaks in both clouds, and made a more fair comparison by isolating the less active Tail region in Orion A and by convolving the Pipe Nebula map to simulate placing it at a distance similar to that of the Orion Complex. The peak mass distributions for Orion A, the Tail, and the convolved Pipe, have similar ranges, sharing a maximum near 5 $M_\odot$, and a similar power law drop above 10 $M_\odot$. Despite the clearly distinct evolutive stage of the clouds, there are very important similarities in the physical and spatial distribution properties of the column density peaks, pointing to a scenario where they form as a result of uniform fragmentation of filamentary structures across the various scales of the cloud, with density being the parameter leading the fragmentation, and with clustering being a direct result of thermal fragmentation at different spatial scales. Our work strongly supports the idea that the formation of clusters in GMC could be the result of the primordial organization of pre-stellar material.

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54 Effect of nucleation on icy pebble growth in protoplanetary discs

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Solid particles in protoplanetary discs can grow by direct vapour deposition outside of ice lines. The presence of microscopic silicate particles may nevertheless hinder growth into large pebbles, since the available vapour is deposited predominantly on the small grains that dominate the total surface area. Experiments on heterogeneous ice nucleation, performed to understand ice clouds in the Martian atmosphere, show that the formation of a new ice layer on a silicate surface requires a substantially higher water vapour pressure than the deposition of water vapour on an existing ice surface. In this paper, we investigate how the difference in partial vapour pressure needed for deposition of vapour on water ice versus heterogeneous ice nucleation on silicate grains influences particle growth close to the water ice line. We developed and tested a dynamical 1D deposition and sublimation model, where we include radial drift, sedimentation, and diffusion in a turbulent protoplanetary disc. We find that vapour is deposited predominantly on already ice-covered particles, since the vapour pressure exterior of the ice line is too low for heterogeneous nucleation on bare silicate grains. Icy particles can thus grow to centimetre-sized pebbles in a narrow region around the ice line, whereas silicate particles stay dust-sized and diffuse out over the disc. The inhibition of heterogeneous ice nucleation results in a preferential region for growth into planetesimals close to the ice line where we find large icy pebbles. The suppression of heterogeneous ice nucleation on silicate grains may also be the mechanism behind some of the observed dark rings around ice lines in protoplanetary discs, as the presence of large ice pebbles outside ice lines leads to a decrease in the opacity there.

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55 Influence of the Disk Wind on the Intrinsic Polarization of Young Stars

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The behavior of the linear polarization parameters of UX Ori stars during their eclipses by circumstellar dust clouds is studied. A circumstellar disk with a disk wind creating a puffing in the dust sublimation zone is considered. We show that the disk puffing can strongly affect the degree of polarization and color index of the star during its eclipse. A strong wind can change the orientation of the plane of linear polarization. The scattered radiation from a thin disk is polarized perpendicularly to its plane, but the radiation from a disk with a strong wind can be polarized along the disk plane. A situation where the disk-scattered radiation is not polarized in a certain spectral band is possible owing to the disk puffing. There can be different orientations of the linear polarization of the disk radiation in different spectral bands.

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56 The CARMA-NRO Orion Survey: Core Emergence and Kinematics in the Orion A Cloud

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We have investigated the formation and kinematics of sub-mm continuum cores in the Orion A molecular cloud. A comparison between sub-mm continuum and near infrared extinction shows a continuum core detection threshold of $A_V \sim$ 5-10 mag. The threshold is similar to the star formation extinction threshold of $A_V \sim 7$ mag proposed by recent work, suggesting a universal star formation extinction threshold among clouds within 500 pc to the Sun. A comparison between the Orion A cloud and a massive infrared dark cloud G28.37+0.07 indicates that Orion A produces more dense gas within the extinction range 15 mag $< A_V <$ 60 mag. Using data from the CARMA-NRO Orion Survey, we find that dense cores in the integral-shaped filament (ISF) show sub-sonic core-to-envelope velocity dispersion that is significantly less than the local envelope line dispersion, similar to what has been found in nearby clouds. Dynamical analysis indicates that the cores are bound to the ISF. An oscillatory core-to-envelope motion is detected along the ISF. Its origin is to be further explored.

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Masses and Implications for Ages of Low-Mass PMS Stars in Taurus and Ophiuchus

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The accuracy of masses of pre-main sequence (PMS) stars derived from their locations on the Hertzsprung-Russell Diagram (HRD) can be tested by comparison with accurate and precise masses determined independently. We present 29 single stars in the Taurus star-forming region (SFR) and 3 in the Ophiuchus SFR with masses measured dynamically to a precision of at least 10%. Our results include 9 updated mass determinations and 3 that have not had their dynamical masses published before. This list of stars with fundamental, dynamical masses, M_{dyn}, is drawn from a larger list of 39 targets in the Taurus SFR and 6 in the Ophiuchus SFR. Placing the stars with accurate and precise dynamical masses on HRDs that do not include internal magnetic fields underestimates the mass compared to M_{dyn} by about 30%. Placing them on an HRD that does include magnetic fields yields mass estimates in much better agreement with M_{dyn}, with an average difference between M_{dyn} and the estimated track mass of 0.01 ± 0.02 $M_\odot$. The ages of the stars, 3–10 MY on tracks that include magnetic fields, is older than the 1–3 MY indicated by the non-magnetic models. The older ages of T Tauri stars predicted by the magnetic models increase the time available for evolution of their disks and formation of the giant gas exoplanets. The agreement between our M_{dyn} values and the masses on the magnetic field tracks provides indirect support for these older ages.

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58 The origin of R CrA variability: A complex triple system hosting a disk

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R CrA is the brightest member of the Coronet star forming region and it is the closest Herbig AeBe star with a spectrum dominated by emission lines. Its luminosity has been monitored since the end of the 19th century, but the origin of its variability, which shows a stable period of 65.767 ± 0.007 days, is still unknown. We studied photometric and spectroscopic data for this star to investigate the nature of the variability of R CrA. We exploited the fact that near infrared luminosity of the Herbig AeBe stars is roughly proportional to the total luminosity of the stars to derive the absorption, and then mass and age of R CrA. In addition, we model the periodic modulation of the light curve as due to partial attenuation of a central binary by a circumbinary disk. This model reproduces very well the observations. We found that the central object in R CrA is a very young (1.5 ± 1.5 Myr), highly absorbed ($A_V = 5.47 \pm 0.4$ mag) binary; we obtain masses of $M_A = 3.02 \pm 0.43$ M$_\odot$ and $M_B = 2.32 \pm 0.35$ M$_\odot$ for the two components. We propose that the secular decrease of the R CrA apparent luminosity is due to a progressive increase of the disk absorption. This might be related to precession of a slightly inclined disk caused by the recently discovered M-dwarf companion. Thus, R CrA may be a triple system hosting a disk.

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59 First Sub-pc Sale Mapping of Magnetic Fields in the Vicinity of a Very Low Luminosity Object, L1521F-IRS

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L1521F is found to be forming multiple cores and it is cited as an example of the densest core with an embedded VeLLO in a highly dynamical environment. We present the core-scale magnetic fields (B-fields) in the near vicinity of the VeLLO L1521F-IRS using submm polarization measurements at 850 μm using JCMT POL-2. This is the first attempt to use high-sensitivity observations to map the sub-parsec scale B-fields in a core with a VeLLO. The B-fields are ordered and very well connected to the parsec-scale field geometry seen in our earlier optical polarization observations and the large-scale structure seen in Planck dust polarization. The core scale B-field strength estimated using Davis-Chandrasekhar-Fermi relation is 330 ± 100 μG which is more than ten times of the value we obtained in the envelope (envelope in this paper is "core envelope"). This indicates that B-fields are getting stronger on smaller scales. The magnetic energies are found to be 1 to 2 orders of magnitude higher than non-thermal kinetic energies in the envelope and core. This suggests that magnetic fields are more important than turbulence in the energy budget of L1521F. The mass-to-flux ratio of 2.3 ± 0.7 suggests that the core is magnetically-supercritical. The degree of polarization is steadily decreasing towards the denser part of the core with a power law slope of -0.86.

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Magnetic fields in the infrared dark cloud G34.43+0.24

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We present the B-fields mapped in IRDC G34.43+0.24 using 850 μm polarized dust emission observed with the POL-2 instrument at JCMT. We examine the magnetic field geometries and strengths in the northern, central, and southern regions of the filament. The overall field geometry is ordered and aligned closely perpendicular to the filament's main axis, particularly in regions containing the central clumps MM1 and MM2, whereas MM3 in the north has field orientations aligned with its major axis. The overall field orientations are uniform at large (POL-2 at 14″ and SHARP at 10″) to small scales (TADPOL at 2.5″ and SMA at 1.5″) in the MM1 and MM2 regions. SHARP/CSO observations in MM3 at 350 μm from Tang et al. show a similar trend as seen in our POL-2 observations. TADPOL observations demonstrate a well-defined field geometry in MM1/MM2 consistent with MHD simulations of accreting filaments. We obtained a plane-of-sky magnetic field strength of 470±190 μG, 100±40 μG, and 60±34 μG in the central, northern and southern regions of G34, respectively, using the updated Davis-Chandrasekhar-Fermi relation. The estimated value of field strength, combined with column density and velocity dispersion values available in the literature, suggests G34 to be marginally critical with criticality parameter λ values 0.8±0.4, 1.1±0.8, and 0.9±0.5 in the central, northern, and southern regions, respectively. The turbulent motions in G34 are sub-Alfvénic with

Alfvénic Mach numbers of 0.34±0.13, 0.53±0.30, and 0.49±0.26 in the three regions. The observed aligned B-fields in G34.43+0.24 are consistent with theoretical models suggesting that B-fields play an important role in guiding the contraction of the cloud driven by gravity.

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A study of accretion and disk diagnostics in the NGC 2264 cluster

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Understanding disk dissipation is essential for studying how planets form. Disk gaps and holes, which almost correspond to dust-free regions, are inferred from infrared observations of T Tauri stars (TTS), indicating the existence of a transitional phase between thick accreting disks and debris disks. Transition disks are usually referred to as candidates for newly formed planets. We searched for transition disk candidates belonging to NGC 2264. We characterized accretion, disk, and stellar properties of transition disk candidates and compared them to systems with a full disk and diskless stars. We modeled the spectral energy distribution (SED) of a sample of 401 TTS, with Hyperion SED fitting code using photometric data from the U band to the MIPS band. We used the SED modeling to distinguish transition disk candidates, full disk systems, and diskless stars. We classified 52% of the sample as full disk systems, 41% as diskless stars, and 7% of the systems as transition disk candidates, among which seven systems are new transition disk candidates belonging to the NGC 2264 cluster. The sample of transition disk candidates present dust in the inner disk similar to anemic disks, according to the $\alpha_{\rm IRAC}$ classification, which shows that anemic disk systems can be candidate transition disks. We show that the presence of a dust hole in the inner disk does not stop the accretion process since 82% of transition disk candidates accrete and show Hα, UV excess, and mass accretion rates at the same level as full disk systems. We estimate the inner hole sizes, ranging from 0.1 to 78AU, for the sample of transition disk candidates. In only 18% of the transition disk candidates, the hole size could be explained by X-ray photoevaporation from stellar radiation.

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Near-Infrared Imaging Polarimetry toward M17 SWex

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We conducted near-infrared (JHKs) imaging polarimetry toward the infrared dark cloud (IRDC) M17 SWex, including almost all of the IRDC filaments as well as its outskirts, with the polarimeter SIRPOL on the IRSF 1.4 m telescope.

We revealed the magnetic fields of M17 SWex with our polarization-detected sources that were selected by some criteria based on their near-IR colors and the column densities toward them, which were derived from the Herschel data. The selected sources indicate not only that the ordered magnetic field is perpendicular to the cloud elongation as a whole, but also that at both ends of the elongated cloud the magnetic field appears to bent toward its central part, i.e., large-scale hourglass-shaped magnetic field perpendicular to the cloud elongation. In addition to this general trend, the elongations of the filamentary subregions within the dense parts of the cloud appear to be mostly perpendicular to their local magnetic fields, while the magnetic fields of the outskirts appear to follow the thin filaments that protrude from the dense parts. The magnetic strengths were estimated to be $\sim 70-300\ \mu$G in the subregions, of which lengths and average number densities are ∼3–9 pc and $\sim$2–7$\times10^3$ cm^{-3}, respectively, by the Davis-Chandrasekhar-Fermi method with the angular dispersion of our polarization data and the velocity dispersion derived from the $C^{18}O$ (J = 1–0) data obtained by the Nobeyama 45 m telescope. These field configurations and our magnetic stability analysis of the subregions imply that the magnetic field have controlled the formation/evolution of the M17 SWex cloud.

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63 S and VV Corona Australis: Spectroscopic Variability in Two Young Binary Star Systems

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We used high-resolution near-infrared spectroscopy from the NIRSPEC instrument on the Keck II telescope, taken over multiple epochs spanning five years, to examine two young binary T Tauri star systems, S Corona Australis and VV Corona Australis. The stars in these $1''$–$2''$ separation systems have optically thick circumstellar disks and high extinctions at optical and near-infrared wavelengths. Using a combination of new and archival data, we have determined the spectral types of all the stars in these two systems for the first time, examined the variable NIR veiling, measured the emission line equivalent widths, and created spectral energy distributions. They have similar spectral types (K7–M1) and are at approximately the same evolutionary stage, allowing comparison of the four stars in the two systems. We conclude that S CrA and VV CrA are young binary systems of stars bridging the Class I and Class II evolutionary stages, characterized by high accretion luminosities and variable emission lines.

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64 ALMA observations of fragmentation, sub-structure, and protostars in high-mass starless clump candidates

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The initial physical conditions of high-mass stars and protoclusters remain poorly characterized. To this end we present the first targeted ALMA 1.3 mm continuum and spectral line survey towards high-mass starless clump candidates, selecting a sample of 12 of the most massive candidates (400– 4000 $M_\odot$) within 5 kpc. The joint 12+7 m array maps have a high spatial resolution of ∼3000 au (∼0.8″) and have point source mass-completeness down to $\sim 0.3\ M_\odot$ at 6σ (or 1σ column density sensitivity of 1.1×10^{22} cm^{-2}). We discover previously undetected signposts of low-luminosity star formation from CO (2–1) and SiO (5–4) bipolar outflows and other signatures towards 11 out of 12 clumps, showing that current MIR/FIR Galactic Plane surveys are incomplete to low- and intermediate-mass protostars ($\lesssim 50\ L_\odot$). We compare a subset of the observed cores with a suite of radiative transfer models of starless cores. We find a high-mass starless core candidate with a model-derived mass consistent with $29^{+52}_{-15}\ M_\odot$ when integrated over size scales of 2×10^4 au. Unresolved cores are poorly fit by starless core models, supporting the interpretation that they are protostellar even without detection of outflows. Substantial fragmentation is observed towards 10 out of 12 clumps. We extract sources from the maps using a dendrogram to study the characteristic fragmentation length scale. Nearest neighbor separations when corrected for projection are consistent with being equal to the clump average thermal Jeans length. Our findings support a hierarchical fragmentation process, where the highest density regions are not strongly supported against thermal gravitational fragmentation by turbulence or magnetic fields.

Accepted by ApJ

http://arxiv.org/pdf/1908.10374

65 Investigation of ^{13}C Isotopic Fractionation of CCH in Two Starless Cores: L1521B and L134N

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We have carried out observations of CCH and its two ^{13}C isotopologues, ^{13}CCH and C^{13}CH, in the 84 – 88 GHz band toward two starless cores, L1521B and L134N (L183), using the Nobeyama 45 m radio telescope. We have detected C^{13}CH with a signal-to-noise (S/N) ratio of 4, whereas no line of ^{13}CCH was detected in either the dark clouds. The column densities of the normal species were derived to be $(1.66 \pm 0.18) \times 10^{14}$ cm^{-2} and $(7.3 \pm 0.9) \times 10^{13}$ cm^{-2} (1σ) in L1521B and L134N, respectively. The column density ratios of $N(\mathrm{C^{13}CH})/N(\mathrm{^{13}CCH})$ were calculated to be > 1.1 and > 1.4 in L1521B and L134N, respectively. The characteristic that ^{13}CCH is less abundant than C^{13}CH is likely common for dark clouds. Moreover, we find that the ^{12}C/^{13}C ratios of CCH are much higher than those of HC_3N in L1521B by more than a factor of 2, as well as in Taurus Molecular Cloud-1 (TMC-1). In L134N, the differences in the ^{12}C/^{13}C ratios between CCH and HC_3N seem to be smaller than those in L1521B and TMC-1. We discuss the origins of the ^{13}C isotopic fractionation of CCH and investigate possible routes that cause the significantly high ^{12}C/^{13}C ratio of CCH especially in young dark clouds, with the help of chemical simulations. The high ^{12}C/^{13}C ratios of CCH seem to be caused by reactions between hydrocarbons (e.g., CCH, C_2H_2, l,c-C_3H) and C^+.

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https://arxiv.org/pdf/1908.09983

66 Multi-wavelength observations of protoplanetary discs as a proxy for the gas disc mass

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Recent observations of protoplanetary discs reveal disc substructures potentially caused by embedded planets. We investigate how the gas surface density in discs changes the observed morphology in scattered light and dust continuum emission. Assuming that disc substructures are due to embedded protoplanets, we combine hydrodynamical modelling with radiative transfer simulations of dusty protoplanetary discs hosting planets. The response of different dust species to the gravitational perturbation induced by a planet depends on the drag stopping time — a function of the generally unknown local gas density. Small dust grains, being stuck to the gas, show spirals. Larger grains decouple, showing progressively more axisymmetric (ring-like) substructure as decoupling increases with grain size or with the inverse of the gas disc mass. We show that simultaneous modelling of scattered light and dust continuum emission is able to constrain the Stokes number, St. Hence, if the dust properties are known, this constrains the local gas surface density, $\Sigma_{\rm gas}$, at the location of the structure, and hence the total gas mass. In particular, we found that observing ring-like structures in mm-emitting grains requires St $\gtrsim$0.4 and therefore $\Sigma_{\rm gas} \lesssim 0.4$ g cm^{-2}. We apply this idea to observed protoplanetary discs showing substructures both in scattered light and in the dust continuum.

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http://arxiv.org/pdf/1908.08865

Gravitoviscous protoplanetary disks with a dust component. II. Spatial distribution and growth of dust in a clumpy disk

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Spatial distribution and growth of dust in a clumpy protoplanetary disk subject to vigorous gravitational instability and fragmentation is studied numerically with sub-au resolution using the FEOSAD code.
Hydrodynamics equations describing the evolution of self-gravitating and viscous protoplanetary disks in the thin-disk limit were modified to include a dust component consisting of two parts: sub-micron-sized dust and grown dust with a variable maximum radius. The conversion of small to grown dust, dust growth, friction of dust with gas, and dust self-gravity were also considered.
We found that the disk appearance is notably time-variable with spiral arms, dusty rings, and clumps, constantly forming, evolving, and decaying. As a consequence, the total dust-to-gas mass ratio is highly non-homogeneous throughout the disk extent, showing order-of-magnitude local deviations from the canonical 1:100 value. Gravitationally bound clumps formed through gravitational fragmentation have a velocity pattern that deviates notably from the Keplerian rotation. Small dust is efficiently converted into grown dust in the clump interiors, reaching a maximum radius of several decimeters. Concurrently, grown dust drifts towards the clump center forming a massive compact central condensation (70–100 $M_\oplus$). We argue that protoplanets may form in the interiors of inward-migrating clumps before they disperse through the action of tidal torques. We foresee the formation of protoplanets at orbital distances of several tens of au with initial masses of gas and dust in the protoplanetary seed in the (0.25–1.6) $M_{\rm Jup}$ and (1.0–5.5) $M_\oplus$ limits, respectively. The final masses of gas and dust in the protoplanets may however be much higher due to accretion from surrounding massive metal-rich disks/envelopes.
Dusty rings formed through tidal dispersal of inward-migrating clumps may have a connection to ring-like structures found in youngest and massive protoplanetary disks. Numerical disk models with a dust component that can follow the evolution of gravitationally bound clumps through their collapse phase to the formation of protoplanets are needed to make firm conclusions on the characteristics of planets forming through gravitational fragmentation.

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http://arxiv.org/pdf/1908.10589

Modeling Time Dependent Water Chemistry Due to Powerful X-ray Flares from T-Tauri Stars

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Young stars emit strong flares of X-ray radiation that penetrate the surface layers of their associated protoplanetary disks. It is still an open question as to whether flares create significant changes in disk chemical composition. We present models of the time-evolving chemistry of gas-phase water during X-ray flaring events. The chemistry is modeled at point locations in the disk between 1 and 50 au at vertical heights ranging from the mid-plane to the surface. We find that strong, rare flares, i.e., those that increase the unattenuated X-ray ionization rate by a factor of 100 every few years, can temporarily increase the gas-phase water abundance relative to H can by more than a factor of ∼3–5 along the disk surface (Z/R $\geq$ 0.3). We report that a "typical" flare, i.e., those that increase the unattenuated X-ray ionization rate by a factor of a few every few weeks, will not lead to significant, observable changes. Dissociative recombination of H_3O^+, water adsorption and desorption onto dust grains, and ultraviolet photolysis of water and related species are found to be the three dominant processes regulating the gas-phase water abundance. While the changes are found to be significant, we find that the effect on gas phase water abundances throughout the disk is short-lived (days). Even though we do not see a substantial increase in long term water (gas and ice) production, the flares' large effects may be detectable as time varying inner disk water 'bursts' at radii between 5 and 30 au with future far infrared observations.

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Planetesimals to Terrestrial Planets: collisional evolution amidst a dissipating gas disk

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We present numerical simulations of terrestrial planet formation that examine the growth continuously from planetesimals to planets in the inner Solar System. Previous studies show that the growth will be inside-out, but it is still common practice to assume that the entire inner disk will eventually reach a bi-modal distribution of embryos and planetesimals. For the combinations of disk mass, initial planetesimal radius and gas disk lifetime explored in this work the entire disk never reaches a simple bi-modal mass distribution. We find that the inside-out growth is amplified by the combined effects of collisional evolution of solid bodies and interactions with a dissipating gas disk. This leads to oligarchic growth never being achieved in different places of the disk at the same time, where in some cases the disk can simultaneoulsy support chaotic growth and giant impacts inside 1 au and runaway growth beyond 2 au. The planetesimal population is efficiently depleted in the inner disk where embryo growth primarily advances in the presence of a significant gas disk. Further out in the disk growth is slower relative to the gas disk dissipation, resulting in more excited planetesimals at the same stage of growth and less efficient accretion. This same effect drives mass loss due to collisional grinding strongly altering the surface density of the accreted planets relative to the initial mass distribution. This effect decreases the Mars-to-Earth mass ratios compared to previous works with no collisional grinding. Similar to some previous findings utilizing vastly different growth scenarios these simulations produce a first generation of planetary embryos that are stable for 10–20 Myr, or 5–10 e-folding times of the gas dissipation timescale, before having an instability and entering the chaotic growth stage.

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Kinematic signatures of cluster formation from cool collapse in the Lagoon Nebula cluster NGC 6530

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We examine the mass-dependence of the velocity dispersion of stars in the young cluster NGC 6530 to better understand how it formed. Using a large sample of members we find that the proper motion velocity dispersion increases with stellar mass. While this trend is the opposite to that predicted if the cluster were developing energy equipartition, it is in agreement with recent N-body simulations that find such a trend develops because of the Spitzer instability. In these simulations the massive stars sink to the centre of the cluster and form a self-gravitating system with a higher velocity dispersion. If the cluster has formed by the cool collapse of an initially substructured distribution then this occurs within 1-2 Myr, in agreement with our observations of NGC 6530. We therefore conclude that NGC 6530 formed from much more extended initial conditions and has since collapsed to form the cluster we see now. This

cluster formation model is inconsistent with the idea that all stars form in dense, compact clusters and provides the first dynamical evidence that star clusters can form by hierarchical mergers between subclusters.

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https://arxiv.org/pdf/1908.11398

There is no magnetic braking catastrophe: Low-mass star cluster and protostellar disc formation with non-ideal magnetohydrodynamics

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We present results from the first radiation non-ideal magnetohydrodynamics (MHD) simulations of low-mass star cluster formation that resolve the fragmentation process down to the opacity limit. We model 50 $M_\odot$ turbulent clouds initially threaded by a uniform magnetic field with strengths of 3, 5 10 and 20 times the critical mass-to-magnetic flux ratio, and at each strength, we model both an ideal and non-ideal (including Ohmic resistivity, ambipolar diffusion and the Hall effect) MHD cloud. Turbulence and magnetic fields shape the large-scale structure of the cloud, and similar structures form regardless of whether ideal or non-ideal MHD is employed. At high densities ($10^6 \lesssim n_{\rm H} \lesssim 10^{11}$ cm^{-3}), all models have a similar magnetic field strength versus density relation, suggesting that the field strength in dense cores is independent of the large-scale environment. Albeit with limited statistics, we find no evidence for the dependence of the initial mass function on the initial magnetic field strength, however, the star formation rate decreases for models with increasing initial field strengths; the exception is the strongest field case where collapse occurs primarily along field lines. Protostellar discs with radii $\gtrsim$20 au form in all models, suggesting that disc formation is dependent on the gas turbulence rather than on magnetic field strength. We find no evidence for the magnetic braking catastrophe, and find that magnetic fields do not hinder the formation of protostellar discs.

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https://arxiv.org/pdf/1908.03241

Properties of Density and Velocity Gaps Induced by a Planet in a Protoplanetary Disk

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Gravitational interactions between a protoplanetary disk and its embedded planet is one of the formation mechanisms of gaps and rings found in recent ALMA observations. To quantify the gap properties measured in not only surface density but also rotational velocity profiles, we run two-dimensional hydrodynamic simulations of protoplanetary disks by varying three parameters: the mass ratio q of a planet to a central star, the ratio of the disk scale height h_p to the orbital radius r_p of the planet, and the viscosity parameter α. We find the gap depth δ_Σ in the gas surface density depends on a single dimensionless parameter $K \equiv q^2(h_p/r_p)^{-5}\alpha^{-1}$ as $\delta_\Sigma = (1{+}0.046K)^{-1}$, consistent with the previous results of Kanagawa et al. (2015a). The gap depth ?V in the rotational velocity is given by $\delta_V = 0.007(h_p/r_p)K^{1.38}/(1 + 0.06K^{1.03})$. The gap width, in both surface density and rotational velocity, has a minimum of about $4.7h_p$ when the planet mass M_p is around the disk thermal mass $M_{\rm th}$, while it increases in a power-law fashion as $M_p/M_{\rm th}$ increases or decrease from unity. Such a minimum in the gap width arises because spirals from sub-thermal planets have to propagate before they shock the disk gas and open a gap. We compare our relations for the gap depth and width with the previous results, and discuss their applicability to observations.

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http://arxiv.org/pdf/1908.11065

Systematic Variations of CO Gas Abundance with Radius in Gas-rich Protoplanetary Disks

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CO is the most widely used gas tracer of protoplanetary disks. Its abundance is usually assumed to be an interstellar ratio throughout the warm molecular layer of the disk. But recent observations of low CO gas abundance in many protoplanetary disks challenge our understanding of physical and chemical evolutions in disks. Here we investigate the CO abundance structures in four well-studied disks and compare their structures with predictions of chemical processing of CO and transport of CO ice-coated dust grains in disk. We use spatially resolved CO isotopologue line observations and detailed thermo-chemical models to derive CO abundance structures. We nd that the CO abundance varies with radius by an order of magnitude in these disks. We show that although chemical processes can e ciently reduce the total column of CO gas within 1 Myr under an ISM level of cosmic-ray ionization rate, the depletion mostly occurs at the deep region of a disk. Without su cient vertical mixing, the surface layer is not depleted enough to reproduce weak CO emissions observed. The radial pro les of CO depletion in three disks are qualitatively consistent with predictions of pebble formation, settling, and drifting in disks. But the dust evolution alone cannot fully explain the high depletion observed in some disks. These results suggest that dust evolution may play a signi cant role in transporting volatile materials and a coupled chemical-dynamical study is necessary to understand what raw materials are available for planet formation at di erent distances from the central star.

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http://arxiv.org/pdf/1908.03267

An Episodic Wide-angle Out ow in HH 46/47

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During star formation, the accretion disk drives fast MHD winds which usually contain two components, a collimated jet and a radially distributed wide-angle wind. These winds entrain the surrounding ambient gas producing molecular out ows. We report recent observation of ^{12}CO (2–1) emission of the HH 46/47 molecular out ow by the Atacama Large Millimeter/sub-millimeter Array, in which we identify multiple wide-angle out owing shell structures in both the blue and red-shifted out ow lobes. These shells are highly coherent in position-position-velocity space, extending to $>$ 40–50 km s^{-1} in velocity and 10^4 au in space with well de ned morphology and kinematics. We suggest these out owing shells are the result of the entrainment of ambient gas by a series of outbursts from an intermittent wide-angle wind. Episodic outbursts in collimated jets are commonly observed, yet detection of a similar behavior in wide-angle winds has been elusive. Here we show clear evidence that the wide-angle component of the HH 46/47 protostellar out ows experiences similar variability seen in the collimated component.

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Complex organic chemistry in high-mass star-forming regions

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Ph.D dissertation directed by: Prof. Dr. Karl M. Menten

Ph.D degree awarded: June 2019

The quest for interstellar complex organic molecules (COMs) lies at the heart of astrochemistry. One basic motivation is to figure out how the rich inventory of COMs found in meteorites and comets is connected to interstellar chemistry. While the number of COMs detected in the interstellar medium increases, we wish to understand whether chemical complexity is a natural outcome of interstellar chemistry, which degree of complexity can be reached, and when, where and under which conditions these molecules form and how their occurence evolves from interstellar clouds to planetary systems. Most interstellar COMs were first detected toward the dense and warm parts of high-mass star-forming regions, called hot molecular cores. In particular, Sagittarius B2 (Sgr B2), one of the most active star-forming regions in our Galaxy, is an excellent target to study the production of COMs under extreme physical conditions (high densities, strong radiation field, high cosmic-ray flux). In this thesis we take advantage of the high sensitivity of a new type of imaging spectral line survey made possible by the Atacama Large Millimeter/submillimeter Array (ALMA). It affords studies of the spatial structure and chemical content of active star-forming regions in Sgr B2 in unprecedented detail. We report the detection of three new hot cores in Sgr B2(N), one of Sgr B2's main star-forming sites. In a detailed comparative study, we determine their chemical composition, density, mass, temperature, and spatial structure. We check for association with maser sources and ultra-compact HII regions, signposts of recent high-mass star formation, as well as outfows, to evaluate the evolutionary stage of the hot cores. In the second part of the thesis we analyze their physical evolution from the cold pre-stellar phase to the present time. We use results of previous radiation-magnetohydrodynamical simulations of high-mass star formation and stellar structure calculations combined with a radiative transfer model to derive the thermal history of the sources. We compute time-dependent chemical abundances using the astrochemical code MAGICKAL, focusing especially on selected COMs to investigate in detail the chemical reactions and processes involved in their formation under the extreme conditions that characterize Sgr B2(N). We compare the chemical model results to the abundances derived from the observations toward the hot cores and find that a cosmic-ray ionization rate 50 times higher than the solar neighborhood value best characterizes Sgr B2(N)'s environmental conditions. We are also able to constrain the range of dust temperatures reached during the earlier pre-stellar phase at which COMs form on dust-grain surfaces. We show that COMs still form efficiently with minimum dust temperatures as high as 15 K, but the current chemical composition of the hot cores excludes minimum temperatures higher than 25 K.

New Jobs

Postdoctoral position at IPAG, Grenoble, on exoplanetary atmosphere evaporation models.

A 3yr postdoctoral position is offered at IPAG, Grenoble, starting January 1st, 2020, to develop and/or adapt models of planetary atmosphere evaporation around young stars and predict the observable signatures of such processes. Previous experience in planetary evaporation models will be most valuable. The work will take place at IPAG in the framework of the ERC-funded project SPIDI (http://www.spidi-eu.org), and will involve collaborations with Alain Lecavelier des Etangs (IAP, Paris) and Vincent Bourrier (Obs. Geneve). Applications are to be sent to Jerome.Bouvier@univ-grenoble-alpes.fr by November 15, 2019.

Postdoctoral Positions in Star and Planet Formation

National Institute of Science Education and Research (NISER) Bhubaneswar, India

Looking for hiring highly motivated and bright postdoctoral candidates interested in different areas of Astrochemistry and Radio/Sub-millimeter/Infrared Astronomy to address the physics of star and planet formation.

The candidate will also have access to the IRAM-30m, ALMA Cycle 6 and 7, SOFIA Cycle 7 data as well as NASA's JWST-MIRI guaranteed time observations and will be involved to prepare science case for SKA's Cradle of Life Consortium (Band 6).

PhDs with Astronomy & Astrophysics/Space Science/Planetary Science or relevant background may apply. Candidates with good scientific programming and astronomical data analysis skills are highly encouraged.

Please contact **Dr. Liton Majumdar (Assistant Professor, NISER, Bhubaneswar, India & Visiting Researcher, NASA JPL, Pasadena, USA)** at liton@niser.ac.in with your CV, research interest and statement addressing the scientific objective.

Meetings

Protostars & Planets VII

Kyoto, April 1 (Thu) - 7 (Wed), 2021

We are planning to organize an international conference, Protostars & Planets VII (PP7), at Kyoto in April 2021, which will be the first conference of the series held in Asia. This series of conference has provided important opportunity for the scientists working on the formation of stars and planets. We would like to have a series of review talks summarizing the development in our field in recent years. As in the previous Protostars & Planets Series, we will publish those reviews as a new volume, *PROTOSTARS AND PLANETS VII*, in the Space Science Series of University of Arizona Press. The information of the meeting is the following:

Meeting Name: Protostars & Planets VII (PP7)
Venue: Kyoto International Conference Center, Kyoto, Japan
Date: April 1 (Thu) - 7 (Wed), 2021
Website: http://www.ppvii.org
Call for Chapter Proposals: Winter of 2019

List of Editors:
Shu-ichiro Inutsuka (Nagoya University), Motohide Tamura (University of Tokyo), Yuri Aikawa (University of Tokyo), Takayuki Muto (Kogakuin University), and Kengo Tomida (Osaka University)

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Summary of Upcoming Meetings

Crete III - Through dark lanes to new stars - Celebrating the career of Prof. Charles Lada
23 - 27 September 2019 Crete, Greece
http://crete3.org

The UX Ori type stars and related topics
30 September - 4 October 2019 St. Petersburg, Russia
http://uxors-2019.craocrimea.ru

Planet Formation Workshop 2019
25 - 28 November Tokyo, Japan
http://th.nao.ac.jp/meeting/planet-formation-workshop2019/

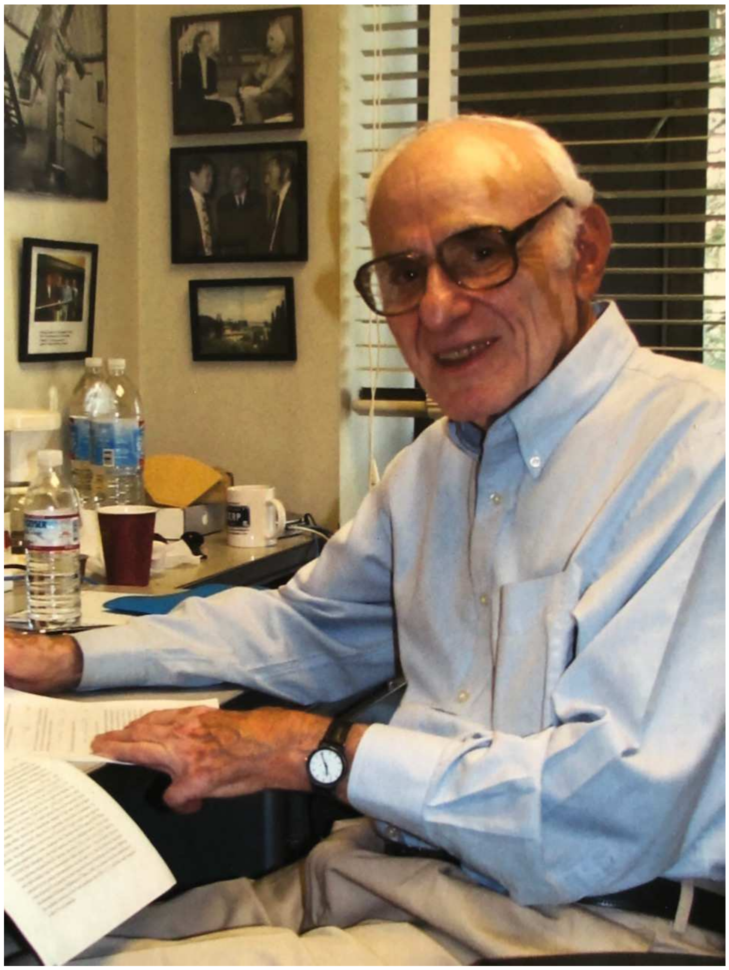
First Stars VI
1 - 6 March 2020 Concepcion, Chile
http://www.astro.udec.cl/FirstStarsVI/

Linking Dust, Ice, and Gas in Space
19 - 24 April 2020, Capri, Italy
http://frcongressi.net/ecla2020.meet

COOL STARS 21: Cambridge Workshop on Cool Stars, Stellar Systems and the Sun
22 -26 June 2020, Toulouse, France
https://coolstars21.github.io/

The Physics of Star Formation: From Stellar Cores to Galactic Scales
29 June - 3 July 2020, Lyon, France
http://staratlyon.univ-lyon1.fr/en

Protostars & Planets VII
1 - 7 April 2021, Kyoto, Japan
http://www.ppvii.org



Alfred E. Glassgold
20 July 1929 - 4 January 2019

Alfred Glassgold, an atomic and nuclear physicist who became an astrophysicist and astrochemist, died in San Francisco on 4 January 2019. His work progressed from atomic nuclei and superfluidity, to interstellar clouds and circumstellar envelopes, to winds from young stars and the birthplaces of planets, illuminating our understanding of these regions of the cosmos. A versatile physicist who was active in teaching and research well into his 80s, he was also a treasured colleague and mentor.

Born 20 July 1929 and raised in Philadelphia, Al was an accomplished clarinetist, who initially considered a career in music but ultimately chose physics as his lifelong pursuit. As an undergraduate, he majored in Physics at the University of Pennsylvania. He later studied theoretical nuclear physics with Victor Weisskopf's group, obtaining his PhD from MIT in 1954. For his postdoctoral studies, Al moved to UC Berkeley, where he worked on problems in statistical mechanics with applications to atomic physics, superfluidity, and nuclear physics. For a few years, he taught with Edward Teller, physics courses to UC students.

In 1963, Al moved with his wife and two children to New York, where he joined the physics faculty at NYU. He was an integral member of the University for 36 years, serving as head of the academic senate as well as chair of the Physics Department during an important period when the department was growing rapidly and its new building was planned and constructed.

Although his initial background was in atomic and nuclear physics, Al's research interests turned to astrophysics in the early 1970s, as a result of the detection of interstellar molecules made by the Charles Townes group using microwave techniques as well as UV observations of interstellar molecules made from space. Simple interstellar molecules had been detected in absorption as early as 1937. However, the detection of molecular emission and the discovery of polyatomic molecules (e.g., ammonia, water) opened up many new avenues of study.

Inspired to use his knowledge of atomic physics to understand the physical conditions in the interstellar medium, Al went to UC Berkeley for a summer to work with Townes, who shared his interest in this topic. It was the beginning of his career as an astrophysicist and an astrochemist. Throughout the 1970s and 1980s, Al and his collaborators, students, and postdocs studied the thermal, chemical, and ionization structure of interstellar clouds and the circumstellar envelopes of late-type stars.

In 1990, Al spent a sabbatical year at UC Berkeley, and his research interests changed direction once again. At the time, Berkeley was a lively focal point for studies on the origins of stars and planets. Al's astrochemistry expertise complemented the theoretical and observational interests of the star and planet formation group, and he began long-term collaborations with Frank Shu and others. His insights contributed to our understanding of the important role atomic winds play in driving molecular outflows and solving a star's "angular momentum problem," i.e., understanding how stars remove enough angular momentum to allow their assembly to proceed.

Al's work on winds also led to studies of protoplanetary disks, the rotationally supported structures around young stars that are the birthplaces of planets. Over the past two decades, he led fundamental work on the ionization structure of disks as well as the molecular and atomic diagnostics that are used to understand their chemical and dynamical nature. These studies demonstrated that stellar X-rays, not cosmic rays, are primarily responsible for disk ionization. The ionization structure of disks governs how they interact with magnetic fields and how they evolve dynamically. Further studies on disk chemistry illustrated how water and other simple molecules can be synthesized in disk atmospheres, and how atmospheres can be heated enough to produce observable emission features, i.e., the signposts that provide clues to their nature.

Much of this later work was carried out after 2000, when Al retired from NYU and joined the UC Berkeley Astronomy faculty. He continued to teach and advise students and postdocs until just a few years ago. Throughout his life, Al read widely on all subjects and enjoyed music, art, and food. Since moving to San Francisco, he had also been closely involved in the political life of the city.

Al is remembered not only for his research accomplishments but also as a treasured mentor and colleague. Unfailingly polite and with a playful sense of humor, he welcomed and encouraged colleagues of diverse backgrounds, including many women astronomers. He is survived by his wife Irene and children, Judith and Eric Glassgold. He is much missed.

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This obituary previously appeared online in Physics Today:
https://physicstoday.scitation.org/do/10.1063/PT.6.4o.20190730a/full/

For an interview with Al Glassgold, see Star Formation Newsletter No. 264

Short Announcements

New book ”Host Stars and their Effects on Exoplanet Atmospheres”

I would like to bring to the attention of the exoplanet community my new book ”Host Stars and their Effects on Exoplanet Atmospheres” published in June 2019 by Springer. I will send the Table of Contents for the book to people who send me an email. The book should be a useful textbook or reference for classes on exoplanets.

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Moving ... ??

If you move or your e-mail address changes, please send the editor your new address. If the Newsletter bounces back from an address for three consecutive months, the address is deleted from the mailing list.

Abstract submission deadline

The deadline for submitting abstracts and other submissions is the first day of the month. Abstracts submitted after the deadline will appear in the following month’s issue.